Cognitive processes influencing prospective memory performance in old age : a cognitive neuroscience approach

Abstract

The aim of this thesis was to contribute to a deeper understanding of cognitive processes influencing prospective memory performance in old age. Prospective memory is defined as the realization of activities intended for future execution. Four studies using cognitive neuroscience methods were conducted. In the first study healthy old adults were compared to patients with impaired executive functions and normal episodic memory showing that their executive, but not their episodic memory deficits, diminish their prospective memory performance. The second study demonstrated that a memory advantage for actions intended for future enactment as compared to actions intended for future report is based on an additional activation of motor brain regions during encoding, indicating that preparatory motor processes enhance their later retrieval. The third study found a similar memory advantage for to-be-enacted actions and a similar brain activation during their encoding for young and old healthy adults, suggesting that these preparatory motor processes are unaffected by aging. In the last study self-reports on everyday prospective memory competence did not discriminate between healthy old adults, patients in the preclinical and mild clinical stage of Alzheimer's disease showing that these seem to be influenced by other than cognitive variables.

Cognitive Processes Influencing Prospective Memory Performance in Old Age: A Cognitive Neuroscience Approach

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Anne Eschen

of Germany

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If any one faculty of our nature may be called more wonderful than the rest, I do think it is memory... The memory is sometimes so retentive, so serviceable, so obedient – at others, so bewildered and so weak – and at others again, so tyrannic, so beyond control !

(Jane Austen, *Mansfield Park*)

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1. Introduction

We usually associate the term *memory* with the retrieval of events we have experienced or of knowledge and skills we have acquired in the past. However, we also use our memory to shape our future behaviour. Every day we are faced with many obligations regarding our work, household, family, and friends, and with our desires to engage in activities for our own pleasure or to reach our own goals. For example, we have to attend work meetings, buy food, pick up our children from school, visit an ill friend, and would like to see a praised theatre play or work out in order to keep fit. Most of these activities cannot be carried out as soon as we decide to take them on, but must be postponed until a later time in the future. Consequently, they must be stored in memory until an appropriate opportunity for their execution arises and at this point remembered to allow for their successful completion. In psychological literature, following Meacham and Leiman (1982), memory for information acquired in the past is referred to as *retrospective memory* and memory for activities we plan to carry out in the future is referred to as *prospective memory*.

Retrospective memory has been a focus of psychological research since the emergence of psychology as a scientific discipline in the end of the 19th century (see Bower, 2000 for a historical overview on retrospective memory research). Since then, for retrospective memory diverse research paradigms have been developed, basic principles of learning, storage, and retrieval of information have been discovered, various retrospective memory types have been distinguished, and brain regions that support these different types of retrospective memory have been identified. There is also a wealth of literature on retrospective memory development over the lifespan, on illnesses that lead to retrospective memory impairments, and on techniques to improve retrospective memory.

Compared to the long tradition of psychological research on retrospective memory, prospective memory research is still in its infancy. Prospective memory has only become into the focus of psychological research about 30 years ago with a general rise of interest among psychologists to study the way people use their memory in daily life, not just under controlled conditions in the laboratory (Cohen, 1996; Morris, 1992). Given the ubiquity of prospective memory demands in everyday life, it is not surprising why prospective memory was discovered as a research topic at that time. However, as McDaniel and Einstein (2007) pointed out, by 1985 only 10 studies on prospective memory had been published. By 1996, Kvavilashvili and Ellis still only found 45 published studies on prospective memory. In 1996, the first book solely dedicated to prospective memory (Brandimonte, Einstein, & McDaniel, 1996) was published. Ever since, there has been an explosion of experimental research on prospective memory: approximately 135 papers on the subject appeared from 1996 to 2000 and over 150 additional papers from 2000 to 2005 (McDaniel & Einstein, 2007). Owing to these rapidly growing research efforts, considerable progress has been made with regard to theoretical conceptualisations and measurement methods of prospective memory. Insights have been gained into cognitive processes involved in and neural correlates of prospective memory, the development of prospective memory from early childhood to old age, and the effects of different neurological and psychiatric illnesses on prospective memory performance. However, compared to the profound knowledge acquired about retrospective memory, a lot of work still remains to be done.

The aim of this thesis is to contribute to a deeper understanding of prospective memory, particularly with regard to its functioning in old age. Aging is accompanied with deterioration of brain structure and function (Hedden & Gabrieli, 2004; Kramer, Fabiani, & Colcombe, 2006), leading to decline in some cognitive abilities (Park, 2000; Schaie, 2005). Furthermore, in old age there is an increase in incidence of neuropathological diseases leading to severe cognitive deficits and impaired everyday functioning (Qiu, De Ronchi, & Fratiglioni, 2007). Three of the four studies included in this thesis investigate how specific cognitive processes thought to be involved in prospective memory are affected by normal aging and in turn influence prospective memory performance of healthy old adults. The fourth study of the thesis explores whether self-reports on everyday prospective memory competence discriminate between healthy old adults and individuals in the early stages of Alzheimer's disease, the most prevalent of the neuropathological diseases in old age. All studies use methods usually adopted in cognitive neuroscience, a new scientific discipline focused on determining the neural substrates of cognitive processes. Thus, in the first study insights about cognitive processes determining prospective memory performance of healthy old adults try to be gained by comparing them to a group of traumatic brain injury patients with a selective cognitive deficit. In the second and third studies, brain activation during a component cognitive process of prospective memory as acquired by functional magnetic resonance imaging will be compared between healthy young and old adults in order to make conclusions about the impact of aging on this cognitive process. In the last study, the association between self-reports on everyday prospective memory competence and the severity of cognitive impairment induced by Alzheimer's disease is investigated.

The thesis starts with a scientific definition of prospective memory, followed by an overview of underlying cognitive processes, an introduction of prospective memory research methods including cognitive neuroscience methods, and a review of findings on prospective memory performance in healthy old adults and Alzheimer patients. Afterwards the main aims and research questions of the four included studies will be introduced, followed by a detailed presentation of the studies. Their main results will be discussed with regard to their more general theoretical, methodological, and practical implications in the final part of the thesis.

1.1. Scientific Definition of Prospective Memory

In the introduction, prospective memory was described as memory for activities planned for future execution. Scientifically, a broader definition of prospective memory is adopted: the term *prospective memory* is used to refer to the whole process of forming intentions to execute certain activities in the future up to their subsequent realization as well as to the cognitive skills that support the successful completion of this process (see Ellis, 1996; Ellis & Kvavilashvili, 2000).

As Ellis and Freeman (2008) pointed out, this conceptualisation of prospective memory is unfortunate in two ways. Firstly, it is an umbrella term used to describe both a type of task as well as the cognitive processes underlying performance in this task. Secondly, it implies that mainly memory processes determine performance in these tasks. However, other cognitive processes such as planning, attention, and action control also seem to influence task performance. In 1996, Ellis therefore proposed to use the descriptor *realizing delayed intentions* instead (with *delayed* capturing the fact that the intended activities cannot be executed immediately, but have to be postponed until a later time in the future). However, this term has not prevailed over *prospective memory*.

Despite the broad general definition of prospective memory, in psychological literature the term is applied only to a subclass of delayed intentions. One restriction imposed on delayed intentions within the framework of prospective memory research is that an intention cannot be kept continually active in working memory during the delay between its formation and its intended execution time (Burgess, Quale, & Frith, 2001; Graf & Uttl, 2001; Maylor, 1996). This constraint was postulated on the one hand to distinguish prospective memory tasks from vigilance tasks and on the other hand to capture a typical feature of many everyday delayed intentions: after their formation, we usually are engaged in other activities that are so demanding that we are not able to constantly think of the activities we intend to carry out later on.

A second restriction is that the future time window for executing the intended activity is constrained (McDaniel & Einstein, 2007) because otherwise it is very difficult to determine whether the completion of a delayed intention was successful or not. For example, the intention to clean the attic sometime in the future would not be regarded as a delayed intention relevant for prospective memory research, but the intention to clean the attic within the next week.

A third restriction imposed on delayed intentions within prospective memory research is that during the intended time window there are no explicit reminders for intention execution (Burgess, Quale, & Frith, 2001; Graf & Uttl, 2001; Maylor, 1996). Thus, to attend a work meeting punctually after being asked by a colleague to accompany him would not be regarded as a successful completion of a prospective memory task. This criterion is often used to distinguish prospective memory tasks from retrospective memory tasks. While in prospective memory tasks retrieval of delayed intentions is self-initiated, in retrospective memory tasks retrieval of previously learned information is prompted by the experimenter (Craik, 1986).

1.2. Cognitive Processes Underlying Prospective Memory Performance

Based on task analyses, several theoretical models regarding cognitive processes underlying successful prospective memory performance have been proposed. They differ greatly from each other in specificity and scope. In the following section the most influential models will be shortly introduced and integrated with the aim to identify major commonly discussed cognitive processes.

Einstein and McDaniel (1990) distinguished two main components of prospective memory tasks with regard to their underlying cognitive processes: a *retrospective component* and a *prospective component*. The retrospective component refers to the content of a delayed intention which has to be stored in memory until its intended execution time and then completely retrieved to allow for its successful realization. Einstein and McDaniel proposed that similar cognitive processes as those involved in retrospective memory tasks support this component. Since in prospective memory research delayed intentions are required to be executed at a specific time in the future and not allowed to be kept active in working memory in the delay between intention formation and execution, they hypothesized that similar processes as those in retrospective *episodic* memory tasks are involved in the retrospective component. The prospective component refers to the *punctual* initiation and execution of the delayed intention at the intended time. Einstein and McDaniel proposed that distinct cognitive processes underlie this component, but did not specify them. Apart from the poor specification of cognitive processes supporting the prospective component this theoretical account neglects that successful prospective memory performance also involves forming a delayed intention.

These disadvantages of Einstein and McDaniel's (1990) model have been overcome by *process models* of prospective memory performance as proposed by Ellis (1996) and Kliegel, Martin, Einstein, and McDaniel (2002). They divided prospective memory tasks in four major phases, i.e., intention formation, retention, initiation, and execution, and discussed cognitive processes underlying successful completion of each of the phases.

According to both author groups, successful completion of the *intention formation* phase mainly depends on planning with regard to how one wants to complete an intended activity and when one wants to complete it. For example, if I want to post a letter tomorrow, I could put it in different post boxes or bring it to different post offices and have to consider the clearing times for the post boxes or the opening times of the post offices and my other engagements during the next day to determine the best way and time to perform this activity. How demanding this planning process is depends on the complexity of the intended activity and on the amount of other activities one has to complete during the intended time period. After the decision, how and when one intends to complete a future activity, one has to encode this delayed intention. Encoding in retrospective episodic memory can be either intentional, i.e., one encodes information deliberately because of an expected need to remember it later on, or incidental, i.e., one does not engage deliberately in encoding, but it takes place automatically as a by-product of information processing (e.g., Brown & Craik, 2000). Encoding in prospective memory is always intentional, since one encodes the delayed intention explicitly for their later execution. According to Ellis (1996), the resulting representation of a delayed intention in memory consists of three elements: a) a representation of the intended activity, b) a representation of the intended time, and c) a representation of the intent, i.e., the degree of readiness or commitment to realize the intention in the future.

The *intention retention* phase refers to the delay until the intended execution time. Over this period, the intention has to be retained in memory while working on other tasks. Ellis (1996) and Kliegel, Martin, Einstein, and McDaniel (2002) proposed that successful completion of this phase consequently mainly depends on retrospective memory processes, i.e., on how well one has encoded the delayed intention during intention formation and can retain it in the light of other information one needs to encode and retain in memory during the delay.

The *intention initiation* phase begins when the time for intention execution arises. Here, on one's own initiative, one has to identify this point in time as the intended moment for intention execution, retrieve the delayed intention, possibly interrupt ongoing activities, and initiate the execution of the intended activity. With regard to cognitive processes involved in the identification of the intended execution time and the retrieval of the delayed intentions, two major types of prospective memory tasks have been distinguished (Einstein & McDaniel, 1990, 1996). For *time-based* prospective memory tasks, the intended execution time is signalled by a particular time (e.g., 10 a.m.) or by the passage of a certain amount of time (e.g., after 10 minutes). For *event-based* prospective memory tasks, the intended execution time is signalled by the occurrence of a certain event (e.g., when I meet my grandmother, when I passed a post box, when I arrive at home).

The occurrence of some events such as eating lunch may give us a rough estimate of time, but in order to determine the exact time we need to check a clock. Therefore, it is generally assumed that the identification of the intended execution time in time-based prospective memory tasks depends on time monitoring, i.e., occasionally checking the clock during the delay between intention formation and the intended time point, and, therefore, on occasional self-initiated retrieval of the delayed intention as a prerequisite for these clock checks (see Kvavilashvili & Ellis, 1996; Einstein & McDaniel, 2007).

For event-based prospective memory tasks, there is disagreement on whether they also involve such monitoring and self-initiated retrieval processes. Smith (2003, 2008; see also Smith & Bayen, 2004) in her *Preparatory Attentional and Memory Processes Theory* claimed that event-based prospective memory does always involve monitoring in the sense that in the delay between intention formation and intended execution time all occurring events are evaluated with regard to whether they are the event representing the time for intention execution or not. However, this monitoring may not be necessarily conscious as it is proposed to be for time-monitoring (for a review on detailed theoretical models on conscious monitoring for the intended time or event see Guynn, 2008). In contrast, McDaniel, Robinson-Riegler, and Einstein (1998, see also Guynn, McDaniel, & Einstein, 2001) in their *associative memory system model* proposed that when the memory trace of a delayed intention is strong enough and the target event consciously processed, the delayed intention is delivered into awareness automatically and, thus, no monitoring for the target event or self-initiated retrieval of the delayed intention are necessary.

McDaniel and Einstein (2000) reconciled both accounts in their *multiprocess framework*. This theory posits that whether controlled processes such as monitoring and self-initiated retrieval or more automatic processes such as automatic retrieval are engaged in event-based prospective memory tasks depends on characteristics of an event-based prospective memory task as well as on an individuals' decision to engage in one type of process or the other. With regard to task characteristics, McDaniel and Einstein proposed that automatic retrieval processes are engaged when an target event is very distinct so that it automatically captures attention, the association between target event and intended activity is high, the activity one is engaged in at the occurrence of the target event is not very demanding, and the target event is in the focus of attention during this ongoing activity. For example, when we want to buy bread on our way home, this intention will more likely automatically pop up in our mind when we pass a supermarket with an eye-catching advertisement, when we pass our usual supermarket as opposed to one we have never been in before, when we are not engaged in a lively chat with a companion, and when we are looking at shop displays and not at the people passing us. With regard to an individual's decision to engage in controlled or automatic processes for completion of an event-based prospective memory task, McDaniel and Einstein suggested that it may depend on her or his general preference for one process type or the other. Moreover, one is more likely to rely on automatic retrieval of the delayed intention when the amount of tasks a person is generally engaged in during the delay between intention formation and intended execution time is high and the delayed intention is regarded as rather unimportant.

During *intention execution*, the intended activity has to be carried out as previously planned. According to Ellis (1996) and Kliegel, Martin, Einstein, and McDaniel (2002), the more complex and novel an intended activity, the more its successful execution will depend on executive control processes, whereas the successful completion of simple and over-learned activities will depend on routine skills. For instance, preparing a meal is a quite complex activity since it requires the execution of different actions in a certain order, whereas putting a letter into a post box is a very simple activity.

To summarize, successful prospective memory performance seems to depend on the interplay of episodic memory processes (encoding, retention, and retrieval), of executive functions (planning, monitoring, inhibition, or action control), and of routine skills for activity execution. Depending on specific task characteristics, such as the nature of the intended activity, the intended time, and the ongoing activities in the delay between intention formation and intended execution time, on individual preferences of a person completing the task, and on task phase different cognitive processes will be recruited. Successful performance in intention formation most likely depends on planning, in intention retention on encoding and retention, in intention initiation on retrieval and action initiation as well in certain cases (in time-based tasks, in event-based tasks with non-distinct, non-focal target-events, low association between target event and intended activity, and demanding ongoing activities; personal choice) on monitoring and inhibition (when an ongoing activity needs to be interrupted), and in intention execution, depending on the nature of the intended activity, on routine skills or executive control processes. Figure 1 presents a schematic overview of the prospective memory phases and putative cognitive processes underlying successful completion of each phase.

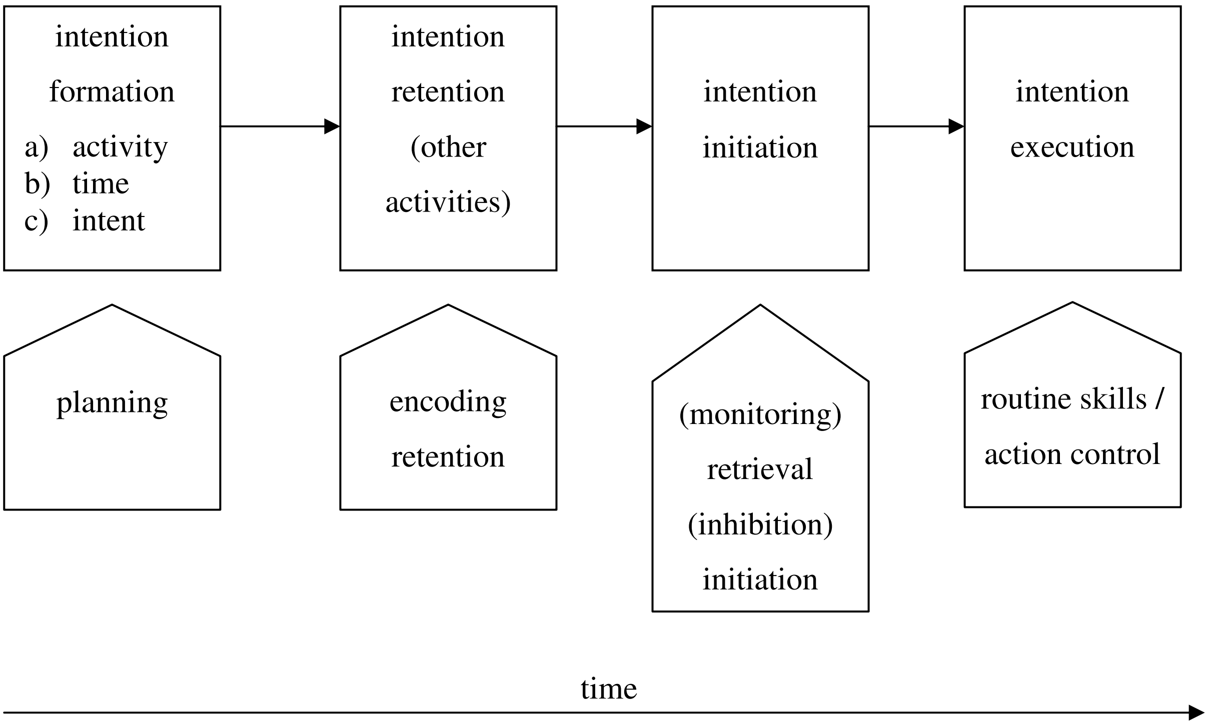

Figure 1. **Prospective Memory Phases and Putative Underlying Cognitive Processes.**
Note: Adapted from Kliegel, Mackinley, & Jäger (2008b).

1.3. Methods of Prospective Memory Research

Progress in a field of science is determined not only by the quality of theoretical conceptions of the topic of interest, but also by the application of appropriate methods to measure predictions made by these theories. Since prospective memory involves several phases and is influenced by many different variables, the development of suitable measurement techniques is quite challenging. However, prospective memory researchers have successfully met this challenge and have devised diverse methods which will be presented below with a short discussion of their strengths and weaknesses.

1.3.1. Field research methods

Since the discovery of prospective memory as a research topic was based on a general interest to study how people use their memory in everyday life, initially research on prospective memory was based on *field experiments*. The main feature of field experiments is that participants are given prospective memory tasks by the experimenter and asked to complete them in their natural environment (Kvavilashvili, 1992). For example, people are asked to send postcards (e.g., Meacham & Singer, 1977; Patton & Meit, 1993), make phone calls (e.g., Devolder, Brigham, & Pressley, 1990; Maylor, 1990), or press buttons on electronic badges (Sellen, Louie, Harris, & Wilkins, 1997; Wilkins & Baddeley, 1978) at pre-specified times over several days or weeks. A great disadvantage of this method is that the experimenter cannot control how participants tackle the task. Specifically, they may use memory aids, such as diaries or mobile phones, or ask a family member to remind them of the experimental task. In that case, a requirement made on prospective memory tasks, i.e., no explicit reminders for the intended execution time, is not met. Furthermore, performance on these tasks will be affected by the amount of other tasks an individual is engaged in during the experimental period. This amount will vary greatly between different persons as well as between different periods in a person's life.

To determine how many and what types of delayed intentions people have to manage in their daily life, which of these they are able to complete, which not and why, some *diary studies* have been conducted (e.g., Ellis & Nimmo-Smith, 1993; Marsh, Hicks, & Landau, 1998). In these studies, the participants are asked to record their everyday delayed intentions for a period of time, such as a day or a week. After the passage of this period, they are asked to record whether they executed their delayed intentions in time and the reasons when they did not. However, participation in such studies is quite effortful and time-consuming, and the participants' motivation may dwindle in the course of time. Moreover, they may forget some delayed intentions or forget to record them.

Another method for investigating everyday prospective memory performance are *questionnaires*. So far (Thöne-Otto & Walther, 2008), three questionnaires have been created to specifically measure everyday prospective memory: the Prospective Memory Questionnaire (PMQ; Hannon, Adams, Harrington, & Fries-Dias, 1995), the Comprehensive Assessment of Prospective Memory (CAPM; Waugh, 1999), and the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie, & Maylor, 2000). In all these questionnaires, people are asked to rate the frequency of different types of everyday prospective memory failures. Additionally, the PMQ assesses strategy use, the CAMP the perceived severity of and reasons for the prospective memory failures, and the PRMQ everyday retrospective memory failures. Questionnaires have the advantage of taking only a short time to complete. They can be distributed easily to a large number of people and, thus, norms with regard to average answers by different samples, such as people of different ages or patients with different disorders, can be easily generated. This in turn allows for the classification of an individual's everyday memory performance as normal or abnormal in comparison to a specific reference sample. A clear limitation of the questionnaire method is that subjective ratings of everyday memory performance have been found to be influenced by other variables than actual everyday memory performance, such as personality traits (e.g., Comijs, Deeg, Dik, Twisk, & Jonker, 2002; Hänninen et al., 1994), depressive affect (e.g., Jonker, Geerlings, & Schmand, 2000; Zimprich, Martin, & Kliegel, 2003), or, particularly in neurological patients, by forgetting or denial of failures (Shum, Fleming, & Neulinger, 2002). Among the three prospective memory questionnaires, the PRMQ provides the best norms (Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Rönnlund, Mäntylä, & Nilsson, 2008) and is most carefully validated with regard to the association of its prospective memory scale with actual prospective memory performance (Mäntylä, 2003; Kliegel & Jäger, 2006, Zeintl, Kliegel, Rast, & Zimprich, 2006).

1.3.2. Laboratory research methods

After the initial focus on everyday prospective memory, interest turned soon to the identification of basic cognitive processes underlying prospective memory performance. Consequently, laboratory research soon prevailed over field research. In laboratory research, people are asked to come to the researchers' laboratories and to perform prospective memory tasks under the researchers' supervision (Kvavilashvili, 1992). Thus, a great advantage of laboratory in comparison to field research is that major variables influencing prospective memory performance, i.e., characteristics of the individuals, the tasks, and the environment, can be controlled and manipulated.

Three major experimental paradigms for laboratory prospective memory research have been developed. The most commonly used paradigm was devised by *Einstein and McDaniel* in *1990*. At the beginning of this paradigm, study participants are asked to perform a certain activity when in a specified later task (termed the *ongoing task*) a certain stimulus occurs (event-based version) or whenever a certain amount of time has passed after the beginning of this task (time-based version). This is thought to reflect a delayed intention. Afterwards, the participants are engaged in other filler tasks. During the ongoing task, there are usually several occasions for intention execution. How often the participants succeed in performing the instructed activity at these occasions is used as a measure for prospective memory performance. Subsequently, the participants are asked to recall the delayed intention they were instructed at the start of the experiment. This is used as a measure for intention retention.

Usually the ongoing task is presented on a computer and requires key presses as responses. The intended activity consists of pressing another key. In the time-based version, the participants can check the time by pressing an additional key. The amount and the distribution of these key presses are used as measures for time monitoring. The experimental paradigm by Einstein and McDaniel (1990) captures important characteristics of delayed intentions in that there is a filled delay between intention formation and intended execution time and no explicit reminders for the intended execution time. In addition to a measure for overall prospective memory performance, the paradigm also provides measures for intention retention and time monitoring and allows for manipulation of task characteristics proposed to influence prospective memory performance, such as the nature of the ongoing task, the intended time, and the interaction between the two. However, its scope is limited. The paradigm does not measure intention formation: the participants do not have to form a delayed intention by themselves, but are given a delayed intention by the experimenter. The intended activity is very simple and, thus, demands on memory and action control are low. Furthermore, since several occasions for intention execution are integrated in the ongoing task, the participants are required to switch continuously between the ongoing and prospective memory task, which is a feature of only a subclass of delayed intentions. Finally, it does not provide separate measures for intention initiation and execution.

Kliegel, McDaniel, and Einstein (2000) have developed an experimental paradigm that overcomes many of the shortcomings of the Einstein-McDaniel-paradigm. In this paradigm, the participants are required to form a delayed intention by themselves. It also provides separate measures for all four prospective memory phases. Moreover, the intended activity is complex and, therefore, demands on memory and action control are higher. In the beginning of the paradigm by Kliegel and colleagues, participants are instructed that they have to perform a complex task after filling in their date of birth in a participant information form that they will receive later on. Then the complex task is introduced and the participants are asked to plan how they want to solve this task later on. Their plan is recorded and its elaborateness is scored. This elaborateness score serves as the measure for intention formation. After about 20 min filled with distracter tasks, the participants are asked to recall their plan for the complex task. Its accuracy relative to the plan previously stated in the intention formation phase is used as the measure for intention retention. Next, the participants are again engaged for about 20 min in distracter tasks. Subsequently, they receive the participant information form. Whether or not the participants initiate the complex task after filling in their birthday serves as the measure for intention initiation. If a participant does not start the task after having finished the entire questionnaire, the experimenter prompts them to do so. Intention execution is measured by how well the participants put their previously formed plan into action and by overall task performance. The complex task the participants need to solve is a modified version of the six-elements task devised by Shallice and Burgess (1991). Six sub-tasks need to be worked on within 6 min. The six sub-tasks are divided into two similar sets (sets A and B) of three different types (finding words, solving arithmetic problems, and writing down the names of pictures). Two rules need to be followed: a) all six sub-tasks have to be initiated within the given time limit, and b) it is not allowed to sequentially work on two sub-tasks (A) and (B) of the same type. A weakness of this paradigm is that it focuses mainly on the intended activity: participants are asked to form a plan only for the intended activity and not for the intended time and intention retention is measured only by recall of the intended activity. Furthermore, the intention initiation measure is not ideal because it is discrete (intention punctually initiated or not), and, therefore, is prone to ceiling or floor effects and not very reliable.

Another influential experimental paradigm that focuses on encoding and retention of delayed intentions was developed by *Goschke and Kuhl (1993)* and later extended by Marsh, Hicks, and Bink (1998) and Freeman and Ellis (2003a). An important characteristic of delayed intentions is that they consist of verbal descriptions of the intended activities and their execution times as well as of the intent to later *execute* them. This differentiates them from verbal materials that are encoded in memory for later verbal report or recognition. Such tasks have been extensively applied in retrospective memory research. Therefore, in Goschke and Kuhl’s paradigm, participants are asked encode two sets of actions. The actions are presented verbally. The participants have to execute one set of actions later. These are thought to represent delayed intentions. For the other set, as in typical retrospective memory tasks, they have to observe the actions being performed by the experimenter and register mistakes or have to verbally report the actions. Afterwards, the accessibility of the two sets of actions in memory is assessed by response latencies to words describing the actions in a subsequent recognition test or lexical-decision task, by the accuracy of the responses in the subsequent recognition test, or by the accuracy of their execution, their observation, or their verbal reports of the actions, respectively. A great disadvantage of this paradigm is that it neglects a requirement made on prospective memory tasks, i.e., that the participants have to initiate delayed intentions by themselves. Moreover, it focuses only on the intended activity and not on the intended execution time as well as on only a subclass of delayed intentions, i.e., those involving motor responses. Verbal report or observation of actions could be reasonably also regarded as intended activities that are part of delayed intentions. However, since in both the Einstein-McDaniel- and the Kliegel-paradigm the intended activities involve motor responses and both only indirectly and marginally investigate encoding and retention of these activities, Goschke and Kuhl's paradigm complements these other two paradigms.

1.3.3. Cognitive neuroscience methods

More recently, for the identification of cognitive processes underlying prospective memory performance cognitive neuroscience methods have been applied in prospective memory research (for a review see Kliegel, Jäger, Altgassen, & Shum, 2008; West, 2008), namely the lesion method, electroencephalography (EEG), positron emission tomography (PET), and functional magnetic resonance imaging (fMRI).

The logic behind the *lesion method* (see Coltheart, 2000; Gazzangia, Ivry, & Mangun, 1998) is that when a cognitive process depends on a certain brain structure, then damage to this structure should disturb this process. Consequently, individuals with damage to this brain structure should perform worse in tasks depending on this process than healthy people. Successful application of the lesion method depends on appropriate control conditions: a) performance of a person or a group of persons with damage to a certain brain region has to be compared with the performance of healthy persons and b) both groups have to complete at least two tasks: an experimental task and a control task. In comparison to the control task, the experimental task should demand an additional cognitive process. If the brain region damaged in the patients supports the additional cognitive process, then the person(s) with brain damage perform(s) worse than healthy individuals in the experimental task and equally well in the control task. Such a result would be called a *single dissociation*. However, often patients with damages to different brain regions show worse performance than healthy controls in a certain experimental task and similar performance as the healthy individuals in the respective control task. Often the conclusion is drawn that these particular experimental and control tasks differ not only in one cognitive process, but in two and that a certain brain region controls one cognitive process and another brain region the other. To test this hypothesis, two new experimental tasks are developed: an experimental task A that differs in one of the new hypothesized cognitive processes (process X) from the former control task and an experimental task B that differs in the other process (process Y) from the former control task. Then a group of patients with damage to one of the brain regions of interest, another patient group with damage to the other brain region of interest, and a healthy control group perform these tasks. Following pattern of findings (named a *double dissociation*) supports the hypothesis of a differential involvement of the two brain regions of interest in the cognitive processes X and Y. The patient group with damage to the brain region supposed to be responsible for cognitive process X performs worse than the control group in experimental task A, the patient group with damage to the brain region supposed to be responsible for process Y performs worse than the control group in the experimental task B. The lesion method has several limitations. First, brain damage to a circumcised brain region is very uncommon. Usually neurological disorders such as stroke, brain injuries, or dementia cause damage to several regions of the brain, and, therefore, patients typically suffer from deficits in many cognitive abilities. Second, even simple tasks usually require an interplay of several cognitive abilities. Consider, for example, reading a word: the font must be perceived, both the letter and the word processed with regard to their sound and meaning. Therefore, it is not easy to devise two tasks that differ only in one cognitive process. Third, there is a great inter-individual variability in location and size of brain structures in the general population as well as in location and size of brain damages in patients. Fourth, the brain is massively interconnected. Thus, several brain regions usually work together to solve one task. Therefore, even damage to a very small brain region may affect more than one cognitive ability. Fifth, it may be unsafe to make assumptions about the functioning of the healthy brain from the performance of people with damage to the brain. It has been shown that the brain reorganizes itself as a result of brain damage such that brain regions not normally recruited for a certain cognitive process are recruited for this cognitive process after brain damage.

Many of the problems inherent in the lesion method are overcome by EEG, PET, and fMRI that can measure brain activity in *healthy people* while they perform cognitive tasks (see Gazzangia, Ivry, & Mangun, 1998; Hüsing, Jäncke, & Tag, 2006). These methods also have the advantage that they can determine which brain regions work together during a certain task. However, as in the lesion method, usually an experimental task and a control task are employed that are thought to differ only in one cognitive process. Brain activity obtained during the control task is subtracted from brain activity obtained during the experimental task. The brain regions that are more activated during the experimental task are considered as the neural substrate of the additional cognitive process involved in this task. Consequently, problems inherent in this technique also apply to EEG, PET, and fMRI.

EEG takes advantage of the fact that neural activity is accompanied by the production of small electrical potentials. When large populations of neurons are active together, they produce electrical potentials large enough to be measured by electrodes placed on the head. Thus, EEG provides a continuous recording of overall brain activity. By averaging EEG traces over a series of trials triggered by a certain stimulus or by a response (called event-related potentials or ERPs), researchers can determine how brain activity is modulated by a certain task. The temporal resolution of ERPs is in the range of ms. In contrast, the spatial resolution of ERPs is limited because it is mathematically impossible to reconstruct a unique intracranial current source for a given EEG signal - an infinite number of sources in the brain can produce the same signal. However, modelling techniques making simplified assumptions about properties of the brain and head tissues and the activity of the neurons have been devised which allow for an estimation of the intracerebral locations of the EEG signals.

PET and *fMRI* measure neural activity indirectly. Neurons require oxygen and glucose in order to perform their functions. When a brain area is more active, more oxygen and glucose are made available to this brain region by increased blood flow to this area. Both PET and fMRI measure local variation in blood flow within the brain associated with the performance of a cognitive task. For *PET*, radioactive elements, called isotopes, are injected into people's bloodstreams. These isotopes decay rapidly and thereby emit positrons. When the positrons collide with electrons gamma rays are created. The PET scanner can detect the location of such gamma rays and reconstructs from the distribution of the gamma rays the distribution of blood flow in the brain.

FMRI exploits the magnetic properties of hemoglobin. Hemoglobin carries oxygen in the bloodstream. When oxygen is absorbed, hemoglobin becomes magnetic. When a brain area is active, initially the amount of oxygenated hemoglobin in this brain area drops. As a reaction, blood flow to this brain region increases. The amount of oxygenated hemoglobin thus provided to the brain area exceeds by far the amount the neurons of the brain region consume. Therefore, in activated brain regions the amount of oxygenated hemoglobin exceeds the amount of deoxygenated hemoglobin. This in turn leads to a change of the magnetic field strength in this brain area which is detected by the MRI scanner.

The temporal resolutions of PET and fMRI are distinctly lower than that of EEG because it takes about 30 s before isotopes injected into the vein enter the brain and about 3 to 8 s before blood flow is directed to an activated brain area as a reaction of a decrease in oxygenated hemoglobin. However, their spatial resolutions are markedly higher. EEG is by far cheaper than PET and fMRI. For PET and fMRI, the study participants have to lie in a bore. FMRI is also sensitive to movement artefacts. Therefore, the head of the participants needs to be fixated in a coil. It is also quite noisy. EEG is less obstrusive for the participants, but the correct fixation of the electrodes takes about 15 to 30 min. Since during fMRI measurement strong magnetic fields need to be generated to detect changes in magnetic field strength caused by changes in the proportion of oxygenated to deoxygenated hemoglobin, metallic objects cannot be taken into the scanner room. Therefore, only certain measurement devices can be used. A big advantage of fMRI in comparison to PET is that it does not require the injection of radioactive material.

So far, it has only been elucidated how cognitive neuroscience methods can be applied to identify neural substrates of cognitive processes. However, when one knows which brain regions support different cognitive processes or which changes in the ERP signal accompany different cognitive processes, these methods can also be applied to determine cognitive processes involved in a certain task. The lesion method can be used for this purpose in the following way: when a group of patients with a specific deficit in one cognitive ability or with damage to a brain region that is known be the neural substrate of this cognitive ability performs as well as a healthy control group in one task but worse in another, both tasks should differ in this cognitive ability. Similarly, brain regions more activated in fMRI or PET in an experimental task as compared to a control task give an indication of the cognitive processes these two tasks differ in. Finally, from changes in ERPs after a certain stimulus one can deduct the order of cognitive processes taking place in response to this stimulus.

Thus, EEG, PET, and fMRI have a great advantage compared to behavioural research or the lesion method. They can provide direct measures of cognitive processes that cannot be observed directly but can only be deducted from task manipulations or performance differences between patients with brain damage and healthy controls. Because of its high temporal resolution EEG has the additional advantage to separate very fast cognitive processes from each other as well as their order.

1.4. Prospective Memory Performance in Healthy Old Adults

Aging is associated with structural as well as functional changes in the brain. Structural changes in aging involve a reduction of the volume of the brain, the size of the neurons, the synaptic density, and the number of neurotransmitters. Functional changes concern reduction in brain activation, in cerebral blood flow, oxygen utilisation, glucose metabolism, and neurotransmitter availability (Dennis & Cabeza, 2008; Kramer, Fabiani, & Colcombe, 2006; Peters, 2002). However, some brain regions seem to be more affected by aging than others and the brain seems long to be able to compensate for these changes. In longitudinal studies on aging, measuring cognitive abilities of the same people repeatingly at different points in their life, have demonstrated that some cognitive abilities stay stable over the whole life span and those that do decline start to deteriorate at different points during the lifespan (Park, 2000; Schaie, 2005). Thus, applying the lesion method, healthy old adults (old usually defined by an age of 60 years and over; see Martin & Kliegel, 2005) can be used to determine cognitive processes involved in prospective memory performance.

As outlined before, executive functions and retrospective episodic memory are supposed to play a major role in prospective memory performance. Based on a great number of empirical findings (see West, 1996 for an overview), there is a general agreement that executive functions are impaired in healthy old adults. In contrast, healthy old adults have been found to be impaired only in some retrospective episodic memory processes (see Craik, 2000 for an overview), but not in others. Intentional encoding as required for encoding of delayed intentions seems to be impaired in healthy old age. Furthermore, self-initiated retrieval processes seem to be impaired in healthy old adults, whereas automatic retrieval processes seem to remain stable. Thus, healthy old adults have been found to be impaired in free recall which is thought to depend on self-initiated retrieval processes, but not in recognition which is assumed to rely on automatic retrieval processes.

Overall prospective memory performance in healthy old adults should be impaired since it is supposed to always depend on executive functions as well as on intentional encoding processes. However, two meta-analyses (Henry, MacLeod, Philipps, & Crawford, 2004; Uttl, 2008) on age-effects in prospective memory performance have found that in laboratory studies using the paradigm by Einstein and McDaniel (1990) young adults (aged usually between 18-30 years) generally outperform old adults, whereas in field experiments which require the participants to complete prospective memory tasks in their natural environment the old adults outperform the young adults. These discrepant findings have mainly been explained by a higher motivation of the old adults to complete the experimental task, their less busy lifestyle, or their greater reliance on memory aids. The few studies conducted so far to test these hypotheses, however, often did not find the proposed age differences for these variables or found no influence of these variables on age differences in naturalistic prospective memory tasks (for a review see Phillips, Henry, & Martin, 2008). Studies in which the Prospective and Retrospective Memory Questionnaire was distributed to a large healthy samples covering the whole adult life span also indicate that everyday prospective memory performance is not impaired in old age (Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Kliegel & Jäger, 2006; Rönnlund, Mäntylä, & Nilsson, 2008; Smith, Della Sala, Logie, & Maylor, 2000; Singer, Falchi, MacGregor, Clerkas, & Spector, 2006; Zeintl, Kliegel, Rast, & Zimprich, 2006). These have generally found no correlation between self-reported everyday prospective memory failures and age (with the exception of Rönnlund et al., 2008; Singer et al., 2006; but in both studies the correlations were small and in contradictory directions). Moreover, despite the general pattern of age-related decline in prospective memory performance as measured in the Einstein-McDaniel-paradigm, there are some studies reporting no age differences (for reviews see McDaniel & Einstein, 2007; Phillips, Henry, & Martin, 2008).

Healthy old adults should be more impaired in prospective memory tasks imposing greater demands on executive functions and retrospective episodic memory processes. Intention initiation in time-based prospective memory tasks is supposed to depend on monitoring and self-initiated retrieval processes, whereas intention initiation in event-based tasks can be achieved by relying solely on automatic retrieval processes. Performance of old adults should, therefore, be worse in time-based than in event-based tasks. In contrast to these predictions, however, in some laboratory studies old adults have been found to perform better on time-based relative to event-based tasks (e.g., d'Ydewalle, Luwel, & Brunfaut, 1999). In addition, in their meta-analysis, Henry and colleagues (2004) found similar age-effects on time-based and on event-based prospective memory tasks using the Einstein-McDaniel-paradigm. Moreover, according to the multiprocess framework by McDaniel and Einstein (2000), event-based prospective memory tasks should impose greater demands on monitoring and self-initiated retrieval processes when the events signalling the intended execution are non-distinct, non-focal to processing carried out in the ongoing task, low associated with the intended activity, and when the ongoing tasks are demanding. Consequently, performance decrements of old adults should be greater in event-based tasks with these properties. In their meta-analysis, Henry and colleagues (2004) sorted the laboratory event-based tasks according to these properties and found greater age-effects for those supposedly demanding more monitoring and self-initiated retrieval processes. However, studies directly manipulating these variables and looking at the effect of these manipulations on the size of performance decrements in old adults as compared to young adults are scarce and are not always support the predictions made by the multiprocess framework (see McDaniel & Einstein, 2007 for a review).

Another intriguing finding from research on prospective memory is that there is an age-invariance for intention retention. This has been found in both the Einstein-McDaniel-paradigm (Henry et al., 2004) and in the Kliegel-McDaniel-Einstein paradigm (Kliegel, Mackinlay, & Jäger, 2008; Kliegel, Martin, McDaniel, & Einstein, 2002; Kliegel, McDaniel, & Einstein, 2000; with the exception of Kliegel, Martin, McDaniel, Einstein, & Moor, 2007). This is hard to reconcile with the deficits reported for old adults in intentional encoding.

Moreover, both paradigms measure intention retention by free recall for the delayed intention. In case of the Einstein-McDaniel-paradigm, the age-invariance in intention retention could be explained by a ceiling-effect because the memory load is very low. However, in the paradigm by Kliegel, McDaniel, and Einstein (2000) the participants have to recall a complex intended activity and still an age invariance has been demonstrated. Studies using the paradigm by Goschke and Kuhl (1993) in young adults have found a memory advantage for action verbs or phrases that were encoded for later execution in comparison to action verbs or phrases that were encoded for later verbal report or observation (Engelkamp, 1997; Freeman & Ellis, 2003a; Goschke & Kuhl, 1993; Jahn & Engelkamp, 1997; Koriat, Ben-Zur, & Nussbaum, 1990, Marsh, Hicks, & Bink, 1998; with the exception of Brooks & Gardiner, 1994). For semantically unrelated action verbs or phrases, a similar memory advantage for young and old healthy adults for to-be-performed versus to-be-reported actions has been observed, but the actual memory performance of the young adults was better than that of the old adults (Freeman & Ellis, 2003b; Norris & West, 1993). For semantically related action phrases, a memory advantage for the to-be-executed actions was only observed for the old adults which lead to the extinction of age differences in memory for to-be-eancted actions, whereas age differences were still found for to-be-reported actions.

These finding seem to suggest that the cognitive processes recruited for storing delayed intentions in memory are somehow unique. Goschke and Kuhl (1993) proposed that delayed intentions are kept in a more active state in memory as compared to other contents without an *intent* to perform activities later. However, Freeman and Ellis (2003a) suggested that the memory advantage for delayed intentions used in prospective memory research is caused by the fact that they involve actions, i.e., motor as opposed to verbal activities. They proposed that during the encoding of verbal action descriptions for later enactment as compared to the encoding of verbal descriptions of actions for later verbal report or observation motor preparatory processes for later action execution take place and that these enhance the accessibility of these actions in memory. Freeman and Ellis (2003a) provided first evidence for this hypothesis by showing that the memory advantage for actions verbs encoded for later enactment versus those encoded for later verbal report is lost when both types of action verbs are enacted during encoding and when a motor interference task, but not a verbal interference task, is introduced concurrent to encoding. Moreover, Freeman and Ellis (2003b) could show that enactment during encoding also disturbs the memory advantage for to-be-enacted versus to-be-reported actions to a similar degree in healthy young and old adults. This indicates that these motor preparatory processes during encoding of actions for later performance seem not to be affected by aging.

In summary, the empirical evidence on overall prospective memory performance of healthy old adults, on their performance in the intention retention phase, and on the size of age differences in prospective memory tasks with different demands on cognitive processes, is often contradictory to predictions made on the basis of theoretical models on underlying cognitive processes of prospective memory performance.

1.5. Prospective Memory Performance in Alzheimer's Disease

Aging is associated with an exponential increase of prevalence of Alzheimer's disease (AD), a slowly progressing and so far incurable neurodegenerative disease (e.g., Ferri et al., 2005; Qiu, De Ronchi, & Fratiglioni, 2007). Clinical diagnosis of AD requires the presence of multiple cognitive deficits and impairment of everyday functioning (see fourth edition of the Diagnostic and Statistical Manual for Mental Disorders, DSM-IV; American Psychiatric Association, 1994). Cognitive decline seems to start about 10 years before clinical AD diagnosis (Almkvist et al., 1998), primarily in retrospective episodic memory and executive functions (for a meta-analysis see Bäckman, Jones, Berger, Laukka, & Small, 2005). Since prospective memory is thought to depend on both of these processes, research on prospective memory in AD has been concentrated on its sensitivity as an early indicator of AD in comparison to retrospective episodic memory.

Only a few studies on this topic have been conducted so far. They all used the paradigm by Einstein and McDaniel (1990), except one questionnaire study. Maylor, Smith, Della Sala, and Logie (2002) found that individuals with *mild to moderate* AD performed worse than healthy elderly controls on prospective memory tasks, but were even more impaired on retrospective memory tasks. Using the Prospective and Retrospective Memory Questionnaire (PRMQ), Smith, Della Sala, Logie, and Maylor (2000) found that both the scale for everyday prospective and the scale for everyday retrospective memory failures discriminated mild to moderate AD patients equally well from healthy old adults. However, Smith and colleagues had asked the carers of the AD patients to complete the PRMQ on the patients' behalf and the objectivity of the carers' judgement was questioned by the finding that the carers evaluated their own everyday prospective and retrospective memory competence better than age-matched healthy control participants.

Duchek, Balota, and Cortese (2006) demonstrated a clear prospective memory deficit relative to healthy controls in a group of old adults with *very mild* AD. They also demonstrated that prospective memory performance helped to discriminate between the very mild AD patients and the healthy old adults above and beyond retrospective memory performance.

Finally, in a large longitudinal population-based study, Jones, Livner, and Bäckman (2006) found that compared to participants who remained healthy, participants who *three years later received an AD diagnosis* showed deficits in prospective and retrospective memory, but these were of equal size. Retrospective memory performance alone best predicted later AD diagnosis, but prospective memory performance additionally improved prediction accuracy.

In summary, these findings indicate that although prospective memory is not a better marker of preclinical or early AD than retrospective memory, it seems to be equally sensitive, and assessment of both types of memory improves discrimination of preclinical and mild AD patients from healthy old adults. However, the empirical evidence on prospective memory performance in AD is also not in line with predictions made on the basis of theoretical models on cognitive processes involved in prospective memory performance. To recap, according to these models prospective memory performance in Alzheimer patients should be more impaired than retrospective memory performance, since it also depends on executive functions.

2. Aims and Research Questions

Starting from the intriguing findings on prospective memory performance in healthy old adults and old patients with Alzheimer's disease, the main goal of this thesis is to contribute to a deeper understanding of prospective memory in old age with the focus on its underlying cognitive processes. For this purpose, four experimental studies were conducted. Their main aims, research questions, experimental strategies, and hypotheses are presented below. The first and the fourth study are covered in separate sections. The second and third studies are presented together in one section, because they are closely related to one another.

2.1. Study 1: The Role of Executive Functions for the Four Phases of Prospective Memory - Comparison of Young and Old Healthy Adults and Traumatic Brain Injury Patients with a Selective Executive Functions Deficit

The *aim* of the first study was to disentangle the respective roles of executive functions and retrospective episodic memory processes in prospective memory performance of healthy old adults in a more detailed way than it has been done so far. It has been suggested that the four phases of the prospective memory process differ in the contributions of executive functions and retrospective episodic memory processes to successful performance. Intention retention is thought to depend on retrospective episodic memory processes only, intention formation and execution on executive functions only, and intention initiation on an interplay of both executive functions and retrospective episodic memory processes (see Ellis, 1996; Kliegel, Martin, Einstein, & McDaniel, 2002). Studies using the paradigm by Kliegel, Einstein, and McDaniel (2000) that provides measures for all phases of the prospective memory process have found so far that healthy old adults perform worse than healthy young adults in only three of the proposed four phases, i.e., intention formation, initiation, and execution. In contrast, for intention retention generally no age differences have been found (for an overview see Kliegel, Mackinley, & Jäger, 2008b). However, for intention initiation is unclear whether the worse performance of the healthy old adults as compared to healthy young adults is caused by their self-initiated retrieval or by their executive functions deficits. Kliegel, Martin, McDaniel, and Einstein (2002) demonstrated in a multiple linear regression analysis on the data of 80 healthy young and old individuals that approximately 50 percent of the performance variance during intention formation, initiation, and execution in the prospective memory paradigm by Kliegel, Einstein, and McDaniel (2000) was predicted by executive functions tests, whereas performance variance in intention retention was not accounted for by any of these tests. Thus, the authors provided preliminary evidence that the worse performance of the old healthy adults as compared to young healthy adults in intention formation, initiation, and execution is caused by their executive functions deficits.

The first study of the thesis tries to support these findings by adopting following *experimental strategy*. A group of traumatic brain injury (TBI) patients with normal retrospective episodic memory according to delayed recall indices of the Wechsler Memory Scale-Revised (Härting et al., 2000) and impaired executive functions as indicated by sum scores on the Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996), a group of healthy old adults, and a group of healthy young adults completed the prospective memory paradigm by Kliegel, Einstein, and McDaniel (2000). In order to compare all three groups directly for executive functions, all three participant groups additionally completed the Wisconsin Card Sorting Test (WCST, Heaton, Chelune, Talley, Kay, & Curtiss, 1993).

Two main *hypotheses* were made. First, if successful completion of the intention formation, initiation, and execution phases depends on executive functions and not on retrospective episodic memory processes, the TBI patients should perform worse than the healthy young adults in these prospective memory phases, but not in intention retention. Second, if the previously found performance decrements of healthy old adults as compared to healthy young adults are based on their executive functions, but not on their retrospective episodic memory deficits, they should show equal performance in all phases of the prospective memory paradigm as the TBI patients.

2.2. Studies 2 and 3: Motor Preparatory Processes in Prospective Memory Encoding in Young and Old Healthy Adults

The general *aim* of the second and third studies of the thesis was to provide more direct evidence for the suggestion that age-invariance in free recall for delayed intentions involving verbal action descriptions is based on the recruitment of motor preparatory processes during encoding that are unaffected by aging. To recap, so far there is only indirect empirical support for this hypothesis. A memory advantage for action verbs encoded for later enactment in comparison to action verbs encoded for later verbal report has been demonstrated. This is lost when the actions are enacted during encoding or when a motor interference task, but not a verbal interference task, is introduced concurrent to encoding (Freeman & Ellis, 2003a). Moreover, this memory advantage is of similar size in healthy young and healthy old adults and is equally affected in both groups when the to-be-enacted and the to-be-reported action verbs are enacted during encoding (Freeman & Ellis, 2003b). To extend these findings, in both studies fMRI was used as it provides more direct measures for cognitive processes involved in encoding.

2.2.1. Study 2: Motor preparatory processes in young adults

The specific *aim* of the second study was to test the proposal that motor preparatory processes are recruited during encoding of delayed intentions involving verbal action descriptions.

Following *experimental strategy* was adopted. A group of young healthy adults was scanned during the encoding of action verbs for later enactment, during the encoding of action verbs for later verbal report, and during the encoding of abstract verbs for later verbal report. Afterwards, the participants were asked to enact or to report the verbs encoded for the respective recall mode.

Two *hypotheses* were posed. First, if motor preparatory are engaged during the encoding of delayed intentions involving action descriptions, then brain regions known to be involved in motor preparation should be more highly activated during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later report. Second, if these brain regions are not only related to a greater retrieval of semantic motor information about the to-be-enacted in comparison to the to-be-reported action verbs, then no overlap between these brain regions and those more highly activated during the encoding of action verbs versus abstract verbs for later verbal report is expected.

2.2.2. Study 3: Motor preparatory processes in young and old adults

The main *aim* of the third study of the thesis was to explore whether the motor preparatory processes that are engaged during the encoding of delayed intentions involving verbal action descriptions are unaffected by aging and lead to the age-invariance in free recall for delayed intentions so far observed in prospective memory research. In the second study of this thesis, the participants had reported that they had imagined themselves or another person executing the to-be-enacted action verbs during encoding, whereas they used more semantic or no specific encoding strategies for the to-be-reported action verbs. In addition, almost all brain regions that were more highly activated during the encoding of the to-be-enacted action verbs have been previously found to be involved in the imagery of actions. Therefore, a second aim of the study was to suppress differential imagery of to-be-enacted action verbs in order to determine to what extent the brain regions more highly activated during the encoding of action verbs for later enactment as opposed to encoding of action verbs for later verbal report in the second study of the thesis were related to imagery of the to-be-enacted actions.

Following *experimental strategy* was adopted. The paradigm of the second study of the thesis was slightly modified. To suppress differential imagery of to-be-enacted action verbs, the participants were not only presented action verbs, but simultaneously short videos of a human model pantomiming the respective actions. Consequently, the condition of encoding of abstract verbs for later verbal report was replaced by a condition in which the participants were asked to simply watch similar action stimuli as those employed in the other two conditions. Moreover, in addition to the subsequent recall test for the to-be-enacted and to-be-reported action verbs, a recognition test was implemented. A group of healthy young and a group of healthy old adults completed this modified paradigm.

Three *hypotheses* were made. First, if the motor preparatory processes engaged during the encoding of delayed intentions involving verbal action descriptions are unaffected by aging, then no difference in brain activation between the healthy young and the healthy old adults during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report should emerge. Second, if these motor preparatory processes cause the age-invariance for free recall of delayed intentions so far observed in prospective memory research, then a similar advantage for to-be-enacted action verbs in comparison to to-be-reported action verbs for healthy young and old adults should be observed in the included retrieval measures as well as a similar performance of the young and the old healthy adults in these retrieval measures for the to-be-enacted action verbs. Third, if the brain regions found to be more highly activated during the encoding of action verbs for later enactment versus later verbal report in the second study of the thesis were only related to differential imagery of the to-be-enacted action verbs, then there should be no overlap between the more highly activated brain regions in this contrast of the second study and the more highly activated brain regions in this contrast of the third study of the thesis.

2.3. Study 4: Self-Reported Everyday Prospective versus Retrospective Memory Competence in Old Healthy Adults, Patients with Mild Cognitive Impairment, and Patients with Mild Alzheimer's Disease

The general *aim* of the fourth study of the thesis was to extend findings on the sensitivity of prospective memory as an early marker for Alzheimer's disease (AD). One line of research on markers for AD has concentrated on self-reports about cognitive decline based on the idea that a person his/herself is best able to notice deterioration of his/her abilities. In addition, these self-reports are quickly and easily to obtain. Since retrospective episodic memory seems firstly and most severely to decline in the progression of AD (e.g., Bäckman, Jones, Berger, Laukka, & Small, 2005), most of the research has focused on self-reports about everyday retrospective episodic memory competence. Although self-reports on everyday retrospective episodic memory competence seem to predict later progression to AD (see Reisberg, & Gauthier, 2008 for an overview), they have been found to correlate poorly with performance on retrospective episodic memory tests and more highly with depressive affect (e.g., Jonker, Geerlings, & Schmand, 2000; Zimprich, Martin, & Kliegel, 2003) or personality traits (e.g., Comijs, Deeg, Dik, Twisk, & Jonker, 2002; Hänninen et al., 1994). Moreover, it has been demonstrated that individuals with retrospective episodic memory deficits have a diminished awareness for them: they evaluate their everyday retrospective episodic memory competence as more positive than relatives or friends who know them well (see McGlynn & Schacter, 1989 for a review). Mäntylä (2003) suggested that people may have a greater insight in their everyday prospective than their everyday retrospective memory competence because prospective memory additionally depends on executive functions, i.e., conscious, self-initiated behaviour. Furthermore, awareness for everyday prospective memory failures should be higher than awareness for everyday retrospective memory failures, because prospective memory failures seem to cause a greater impairment in everyday functioning (Kliegel & Martin, 2003) and have more negative social consequences than retrospective memory failures: they are attributed to a person's lack of reliability, whereas retrospective memory failures are mostly ascribed to a weakness of a person's memory (Winograd, 1988). Starting from Mäntylä's proposal, the specific goals of the fourth study were to evaluate the usefulness of self-reported frequency of everyday prospective in comparison to everyday retrospective episodic memory failures for identifying individuals in the preclinical and mild clinical stage of AD and to determine their respective relations with executive functions in the old healthy adults and in the patients in the preclinical stage of AD.

For this purpose, following *experimental strategy* was adopted. The frequency of self-reported everyday prospective and retrospective memory failures was measured with the Prospective and Retrospective Memory Questionnaire (PRMQ, Crawford, Smith, Maylor, Della Sala, & Logie, 2003). A group of patients with mild AD, a group of patients with Mild Cognitive Impairment (MCI), and a group of healthy old adults completed the PRMQ, a neuropsychological test battery, and a depression questionnaire. MCI is a recently developed diagnostic concept aimed at identifying individuals in the preclinical stage of AD. To evaluate whether insight in everyday prospective memory competence is specifically related to executive functions in the old healthy adults and in the MCI patients, correlations between the scores of the PRMQ prospective and retrospective memory scales and the scores of three executive function tests were calculated separately for the two groups. Since it has been demonstrated that age, education, gender, and depressive affect are related to subjective memory complaints in normal aging (Jonker, Geerlings, & Schmand, 2000; Zimprich, Martin, & Kliegel, 2003) and MCI patients (Kliegel, Zimprich, & Eschen, 2005), correlations between these variables and the PRMQ prospective and retrospective scale scores were also computed separately for the two participant groups and, if applicable, controlled for.

Two *hypotheses* were posed. First, if self-reported everyday prospective memory failures discriminate healthy old adults better from patients in the preclinical and in the mild clinical stage of AD than self-reported everyday retrospective memory failures, then the MCI patients are expected to report more everyday prospective and retrospective memory failures than the healthy old adults, while the AD patients are expected to report more everyday prospective memory failures than the MCI patients, but a similar amount of everyday retrospective memory failures. Second, if awareness for everyday prospective memory failures is based on the dependency of prospective memory performance on executive functions in both healthy old adults and MCI patients, then in both groups self-reports on everyday prospective memory failures should correlate with executive functions tests, whereas self-reports on everyday retrospective memory failures should not.

3. Study 1: The Role of Executive Functions for the Four Phases of Prospective Memory - Comparison of Young and Old Healthy Adults and Traumatic Brain Injury Patients with a Selective Executive Functions Deficit[1]

3.1. Introduction

In the last few years, there has been an enormous increase of research interest in prospective memory, i.e., the processes and skills required to support the delayed fulfilment of a previously planned intention (see Ellis & Kvavilashvili, 2000). Interest in prospective memory is largely based on its significant relevance in everyday life, especially in old adults and neuropsychological patients (see Kliegel & Martin, 2003). Particularly those persons appear to have considerable difficulties in prospective remembering.

Several studies suggest that prospective memory declines early in age. For example, Dobbs and Rule (1987) and Mäntyla and Nilsson (1997) demonstrated in their studies with large samples of participants between 30 and 80 years that prospective memory seems to decline linearly from the 5th decade. Huppert, Johnson, and Nickson (2000) also found a linear decline in prospective memory in their large population–based study of participants 65 years and older.

As for prospective memory performance in neuropsychological patients, prospective remembering seems to be disrupted by many neurological and psychiatric disorders. For example, prospective memory impairments are reported for patients with Herpes Simplex Encephalitis (Sgaramella, Borgo, Fenzo, Garofalo, & Torso, 2000), Korsakoff's Syndrome (Brunfaut, Vanoverberghe, & d'Ydewalle, 2000), Parkinson's disease (Bisiacchi, 2000), early dementia (Huppert & Beardsall, 1993; Huppert et al., 2000), schizophrenia (Meissner, Hacker, & Heilemann, 2001; Ouriache, 2000), depression (Rude, Hertel, Jarrold, Covich, & Hedlund, 1999), and brain injury (Groot, Wilson, Evans, & Watson, 2002; Shum, Valentine, & Cutmore, 1999). Moreover, there are indications that there is an association between the severity of prospective memory deficits and the severity of the traumatic brain injury (McCauley & Levin, 2004). Furthermore, it has been demonstrated that for people with traumatic brain injury prospective memory deficits impair everyday functioning (Kinsella et

[1] A similar version of this chapter has been published as: Kliegel, M.*, Eschen, A.*, & Thöne-Otto, A. I. T. (2004). Planning and realization of complex intentions in traumatic brain injury and normal aging. *Brain and Cognition*, *56*, 43-54. *Both authors contributed equally.

al., 1996) and are the primary obstacles for leading an independent life (Thöne-Otto & Walther, 2001).

To investigate which variables might be related to these deficits in prospective memory performance, theoretically, the delayed realization of an intention has been proposed to be a complex process involving at least four phases (Ellis, 1996; Kliegel, Martin, McDaniel, & Einstein, 2002). In the first phase (i.e., intention formation), one has to form the intention, i.e., to plan which actions shall be performed at what time in the future, and then to encode the plan. According to the way in which performance time is signalled, two kinds of prospective memory tasks have been distinguished (Einstein & McDaniel, 1996). For time-based prospective memory tasks, the intended action is carried out at a particular time or after a certain amount of time has passed; for event-based prospective memory tasks, the intended action is performed when a certain event occurs (Einstein & McDaniel, 1990). In the second phase (i.e., intention retention), one has to keep the intention in mind while working on other tasks. The third phase (i.e., intention initiation) begins when the intended moment for the initiation of the intended action arises. Here, one has to inhibit ongoing activities and initiate the intended plan. The success in this phase depends heavily on how well one monitors the environment for the (time- or event-related) signal to perform the delayed intention (see Kliegel, Martin, McDaniel, & Einstein, 2001, 2004). In the last phase (i.e., intention execution), on one's own initiative, the intended action has to be carried out as previously planned.

As has been suggested from this and similar task analyses (see Burgess & Shallice, 1997; Knight, 1998; Kvavilashvili & Ellis, 1996), prospective memory seems to rely on basic memory skills (i.e., the encoding, retention, and retrieval of the intentions) and even more so on executive functions (i.e., planning the intended action, monitoring the environment for the cue to initiate the intention while performing other tasks, inhibiting these other activities at the critical time to perform the intention, switching to the intended action, and carrying it out as it was planned). It has been demonstrated that patients with moderate to severe traumatic brain injury have deficient retrospective memory skills, particularly in the acquisition (DeLuca, Schultheiss, Madigan, Christodoulou, & Averill, 2000) and retention of information (Vanderploeg, Crowell, & Curtiss, 2001) which might account for prospective memory problems observed in TBI patients.

McDaniel, Glisky, Rubin, Guynn, and Routhieaux (1999) and Kopp and Thöne (2003) explored the role of retrospective memory skills and executive functions for a prospective memory task in old participants or patients with brain injury, respectively. In both studies, using two distinct, rather simple prospective memory tasks, participants were assigned to four groups according to the presence or absence of retrospective memory impairments and/or executive functioning deficits (as identified by neuropsychological tests). Participants with unimpaired executive functions performed better on the prospective memory task than those with executive functioning deficits, regardless of their retrospective memory skills. In contrast, there were no differences between participants with and without retrospective memory deficits. However, Kopp and Thöne (2003) had excluded people from the study who were not able to learn the prospective memory task instructions and allowed for more acquisition trials for individuals with learning deficits. Nevertheless, other findings also suggest that it does not seem to be the most critical part of a prospective memory task to retrospectively recall the content of an intention and that, in fact, recalling an intention content seems to be intact even in severe neuropsychological syndromes. Maylor, Smith, Della Sala, and Logie (2002), for example, found that patients with Alzheimer's disease were able to recall prospective memory task instructions although being impaired on memory tests such as digit span, sentence span, and free recall of a word list. Consequently, retrospective memory of intention content seems to be a necessary prerequisite for the delayed realization of this intention, but otherwise executive functions seem to be of even greater importance for the actual initiation and execution of the delayed intention.

Executive functions are assumed to be, at least in part, based on neuronal processes located in the prefrontal cortex (Burgess, 1997; Levin, Greenberg, & Benton, 1991; Smith & Jonides, 1999). Recent imaging studies have demonstrated an involvement of prefrontal areas in prospective memory tasks (Burgess, Quayle, & Frith, 2001; Okuda et al., 1998; West, Herndon, & Crewdson, 2001). Furthermore, Cockburn (1995), Shallice and Burgess (1991), and Bisiacchi (1996) reported on single cases with focal prefrontal lesions who were impaired in prospective memory tasks. In addition, Shapiro, Shapiro, Russell, and Alper (1998) found that a group of patients with focal prefrontal lesions performed worse on a prospective memory task than a group of patients with focal posterior lesions. In conclusion, there is converging evidence from imaging and lesion studies that prospective memory depends on the functioning of the prefrontal areas.

In accordance with these findings, the deterioration of prospective memory with increasing age is thought to be associated with the age-related decay of prefrontal cortex functions (Glisky, 1996; Kliegel, Ramuschkat, & Martin, 2003a, 2003b; West, 1996). Age-related functional and structural changes appear to be first evident in the prefrontal cortex as compared to other cortical areas around the age of 50 (for an overview see Salat, Kaye, &

Janowsky, 2001; West, 1996). Furthermore, Daigneault, Braun, and Whitaker (1992) and Crawford, Bryan, Luszcz, Obonsawin, and Stewart (2000) demonstrated that executive functions do decline early in old age. Moreover, there are first findings that directly support the hypothesis that age-related decline in prospective memory is linked to age-related deficits in the prefrontal lobe or in executive functioning, respectively. West and Covell (2001) demonstrated that the less efficient prospective memory performance of old people went along with reductions of the amplitude of event-related brain potentials that are thought to reflect frontal neural activity. In addition, Kliegel et al. (2003a), in an hierarchical multiple OLS regression analysis, found that the age-related variance in two prospective memory tasks was completely accounted for by the variance of five executive functions tests: Wisconsin Card Sorting Test (Heaton, Chelune, Talley, Kay, & Curtiss, 1993), Plan-A-Day Test (Funke & Krüger, 1993), Stroop Test (Stroop, 1935), Tower of London (Ward & Allport, 1997), and S-Words Test (Regard, Strauss, & Knapp, 1982).

However, most of the above-mentioned studies exploring the involvement of the prefrontal cortex or executive functions in prospective memory as well as their role in its age- and neuropsychological disease-related decline have employed prospective memory tasks that do not disentangle the outlined phases in the process of the realization of an intended action at an intended time in the future.

Kliegel, McDaniel, and Einstein (2000) have proposed a laboratory procedure that allows for the separate assessment of the four phases of the prospective memory process (i.e., intention formation, intention retention, intention initiation, and intention execution). They found age-related declines in intention formation, intention initiation, and intention execution. Moreover, Kliegel et al. (2002) demonstrated in a multiple linear regression analysis on the data of 80 healthy individuals that approximately 50 percent of the performance variance during intention formation, intention initiation, and intention execution in their prospective memory task were predicted by executive measures whereas the variance in intention retention was not accounted for by any of these measures. Thus, it seems that only intention formation, intention initiation, and intention execution depend on executive functioning. In consequence, one might expect that only in these phases, performance decrements for any individuals with executive functioning deficits should arise - in old adults and in (young) patients with selective deficits in executive functioning.

Continuing with this line of research, it was one aim of the present study to provide further evidence for this differential effect of executive functioning impairments on intention formation, initiation, and execution. Applying an approach of combining healthy old adults with young neuropsychological patients and young healthy controls, the second aim of the study was to investigate if age-related prospective memory decline might be related to executive functioning deficits. Therefore, in the present investigation, a group of patients with a retrospective memory within normal limits but impaired executive functions as a consequence of a traumatic brain injury, a group of healthy old adults, and a group of healthy young adults completed the complex prospective memory task according to Kliegel et al. (2000).

Proceeding from the described previous findings and from the hypothesis that age-related prospective memory decline is associated with the deterioration of executive functioning, it was expected that the patients with the executive functioning deficits and the old healthy adults would perform worse than the young healthy adults in the intention formation, intention initiation, and intention execution phase of the complex prospective memory task. However, all groups should achieve similar results in the intention retention phase, as healthy old adults were not expected do differ substantially from the young neuropsychological patient group.

3.2. Method

3.2.1. Participants

Forty-seven participants were included in the analyses. Seven participants were former patients of the Day-Care Clinic of Cognitive Neurology of the University of Leipzig who met the inclusion criteria: traumatic brain injury (TBI) at least 6 months prior to the study, retrospective memory within normal limits according to delayed recall indices ≥ 85 on the Wechsler Memory Scale- Revised German version (WMS-R; Härting et al., 2000), impaired executive functioning as indicated by age-corrected sum scores < 90 (Matthes-von Cramon & von Cramon, 2000) on the Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson, Aldermann, Emslie, & Evans, 1996), no major psychiatric disorder or any severe perceptual, motor, or language impairments. The other 40 healthy control participants were community dwelling volunteers with no existing or previous psychiatric conditions.

The 7 patients were recruited out of the 534 patients who had been treated in the Day-Care Clinic of Cognitive Neurology since its opening until the time of the study. Overall, there had been 133 patients who had experienced a traumatic brain injury. Out of these, only 59 had shown a retrospective memory within normal limits. Out of these, 2 had to be excluded from the study because they had severe language impairments. Further 12 patients had to be excluded because they were depressive. Out of the remaining 45 patients, 10 showed impaired executive functioning test performance. Out of these patients, we recruited our 7 participants of the study. The other 3 patients could not be contacted anymore, or refused participation. The 7 patients meeting the inclusion criteria participated in the following data assessment and were paid for their participation. Table 1 presents the cause of the TBI, an indication of severity of the TBI (by the length of the posttraumatic coma or posttraumatic amnesia), the amount of months which had passed between the TBI and the time of the study, the location of brain damage as observed in computer tomography or magnetic resonance imaging pictures, the verbal intelligence level (as measured by the Mehrfachwahlwortschatztest-B, MWT-B; Lehrl, 1977), the WMS-R delayed recall index, the age-corrected sum scores of the BADS for each of the included patients as well as the means and standard deviations for the whole patient group if appropriate. As can be deducted from Table 6, all patients had experienced a severe traumatic brain injury (posttraumatic amnesia or posttraumatic coma period between 1.5 and 34.5 weeks). Most of the patients showed a diffuse axonal injury or frontal and temporal damages. In all cases the number of months between the TBI and the study exceeded by far the required 6 months (between 27 and 55 months). The patients showed a verbal intelligence level within normal limits (MWT-B IQ between 91 and 130) and their retrospective memory performance was in the lower average limit (WMS-R delayed recall indices between 87 and 109). The difference between the TBI patients' verbal intelligence level and their retrospective memory level was for 4 of the 6 patients with available data within one standard deviation (difference between -6 and 10), indicating no or a very small potential memory loss caused by the TBI. However, at the time of the study, all patients' retrospective memory performance was within normal limits. The TBI patients' executive functioning test performance was mainly in the rather slightly impaired range (BADS age-corrected sum scores between 81 and 88 besides one patient showing a score of 53).

Of the 40 control participants, 19 were healthy young students (age: M = 24.26 years, SD = 4.34) and 21 were healthy, old members of an English training class in a continuing education institute (age: M = 70.81 years, SD = 5.87).

Table 1. ***Clinical Data and Selection Criteria for the TBI Patients***

Patient	TBI cause	TBI severity	Location of damage	Months since TBI	Verbal intelligence MWT-B	Retro-spective memory WMS-R	Difference between intelligence and memory score	Executive functioning BADS
1	Fall from a height	PTA 8.5 weeks	DAI, brain stem	49	-	94	-	88
2	Grievous bodily harm	PTA 13 weeks	ICH left	42	107	100	7	81
3	Traffic accident	PTA 5.5 weeks	Frontal left, temporal left	36	91	97	-6	81
4	Work accident	PTA 34.5 weeks	Frontal right, temporal right	55	97	87	10	53
5	Traffic accident	PTA 1.5 weeks	DAI	48	124	109	15	83
6	Skiing accident	PTC 3 weeks	Widespread right hemispheric lesion	35	130	95	35	86
7	Traffic accident	PTC 2 weeks	No information available	27	104	100	4	81
M (*SD*)				41.71 (11.79)	108.83 (15.25)	97.43 (6.75)	10.83 (13.76)	79.00 (11.79)

Note. PTC = Posttraumatic Coma. PTA = Posttraumatic Amnesia. ICH = Intracerebral Haemorrhage. DAI = Diffuse Axonal Injury.

3.2.2. Procedure and materials

3.2.2.1. General procedure

At the beginning of the test session, the participants received general information about the test procedure and signed an informed consent form. At the end of the test session, the experimenter debriefed the participants.

3.2.2.2. The complex prospective memory task

The complex, multiple prospective memory task (following Kliegel et al., 2000), that requires participants to plan and - after a delay - realize a set of six sub-tasks, was assessed in four phases. In the first phase, the participants were instructed on the complex prospective memory task set and required to develop an explicit intention on their own how they intended to perform this task set later on (*intention formation: What is the participant planning to do?*). In the second phase, after some distractor tasks were administrated retrospective memory for the previously developed intention was tested (*intention retention: Does the participant still know the content of his/her intention?*). In the third phase, again, distractor tasks were administrated and - at the appropriate moment - the intention had to be initiated (*intention initiation: Does the participant remember him/herself to initiate the intended actions at the appropriate moment?*). In the fourth and final phase, the previously planned intention had to be executed on the participant's initiative (*intention execution: (a) intention fidelity: Does the participant actually follow his/her previously stated intention?* and *(b) self-initiated switching: Does the participant remember to do all planned actions?*).

3.2.2.3. Intention formation phase

According to Kliegel et al. (2000), at the beginning of the complex prospective memory task procedure, participants were instructed that, at a certain point in this session, they would have to fill out a personal information questionnaire ("participant information form" - as noted below, this was the cue for initiating the intention to work on the complex prospective memory task set). The participants were informed that this would take place later in the session.

1) The sub-tasks

Using example sheets, the complex prospective memory paradigm and the rules were explained to the participants. Specifically, the participants were asked to carry out on their own six sub-tasks in a period of 6 min. The six sub-tasks were divided into two similar sets (sets A and B) of three (finding words, solving arithmetic problems, and writing down the names of pictures). Each subtask was designed so that it would need more than one minute to complete. The two sets of word finding problems (based on the MWT-B; Lehrl, 1977) consisted of 35 groups of four items. In each group, there was one word and three similarly spelled or similarly sounding pseudo-words (e.g., conceal - concill - cauncil - concel). The participants' task was to circle the actual words. Each set of arithmetic problems contained 10 problems (e.g., "300/6x4="), and both sets were equivalent in difficulty (as was tested in a pilot study; see Kliegel et al., 2000). Finally, the 20 pictures in each set were pictures of common objects or symbols (e.g., a house). Here, the participants' task was to write down an appropriate label for the pictures. The participants were told that there was not a perfect answer in this sub-task and that they should write down whatever they thought was the best label for the pictures.

2) The rules

After explaining the sub-tasks, participants were told where the material for these sub-tasks was stored (in the second drawer of the participant's table, divided in three file-folders according to the task type) and that there would be a few rules to follow. Specifically, the rules were indicating that all six sub-tasks (words A, words B, math A, math B, pictures A, pictures B) were to be initiated within the given time limit of 6 min. Thus, the rules were designed to require and reward five self-initiated switches from working on one type of task to another type of task within the available 6 min. One major rule to obey was that the participants were not allowed to do two sub-tasks (A) and (B) of the same type (words, math, or pictures), one after the other (see Kliegel et al., 2002; Kliegel, Martin, & Moor, 2003, for more details).

3) Test of instruction comprehension

Afterwards, the participants were tested for recall of the instructions and any errors or omissions were corrected.

4) Prospective memory instruction

When the participants were aware of the task instructions, they were told that, in addition, they would have to open the drawer and start this task set by themselves after answering the question about their date of birth in the "participant information form" that had been previously explained. In addition, they were told that they will have to remember on their own to follow their plan and to remember to switch to all six sub-tasks.

5) Explicit intention formation

Next, the participants were asked to develop an explicit intention how they intended to perform this complex multiple task set. The *intention formation* had to be verbal and was recorded on a tape recorder. According to Kliegel et al. (2000), the elaborateness of the intention was analyzed in terms of a score that included three main features: (1) the number of rules included in the participant's intention (e.g., "Since I'm not allowed to do two tasks of the same type in sequence..."), (2) the number of times a participant specified a particular order for performing a task, including the rationale for this (e.g., "I will do the picture first because I think I can do them more quickly..."), and (3) the number of executable items of the intention. To assess the number of executable items, it was noted how many executable steps the participant indicated, i.e., the number of task-steps he/she planned to initiate (words, pictures, and/or arithmetic problems - 1 point each) and whether the participant specified the steps concerning the version (A or B - 1 point each) and/or concerning the time he/she planned to spend on each step or the amount of items he/she planned to complete in each step (1 point each). The intention-elaboration score was the sum of the number of features (described above) included in the intention. The theoretical minimum score of zero indicates that the participant did not plan at all. The minimum score for the simplest but correct and complete intention is 7 (e.g., recorded intention: "First, I will do all versions A and then all versions B" yields a score of 7). The maximum score is, in principle, unlimited (see Kliegel et al., 2000 for a more detailed description).

6) Hypothesis

From the assumptions outlined above, one would expect that the TBI patients with impaired executive functions and the old healthy participants obtain lower scores on this measure, as it depends critically on executive functions such as planning, problem solving, and fluency in the sense of coming up with several solutions.

3.2.2.4. Intention retention phase

1) Distractor activities

The following intention retention phase lasted about 20 min and was filled with distractor activities (i.e., other cognitive tests such as problem solving tasks required for a distinct study protocol).

2) Retrospective memory for the intention

Afterwards, the participants had to recall their intention for the complex prospective memory task set (*intention retention*), which was scored for accuracy relative to the plan previously stated in the intention formation phase (percentage of executable items of the intention that were correctly recalled).

3) Hypothesis

Proceeding from the assumption that success in this phase mainly depends on retrospective memory skills, one would expect that the TBI patients who were not or only slightly impaired in retrospective memory, the old healthy adults, and the young healthy adults would obtain similar and high scores in the intention retention measure.

3.2.2.5. Intention initiation phase

1) Distractor activities

This was followed by another delay of approximately 20 min filled with distractor activities (see above). In the middle of this delay, there was a 5-min break.

2) Initiation of the intention

The participants were then given the participant-information questionnaire. After having answered the question about their date of birth, participants were supposed to initiate their intention concerning the performance of the complex prospective memory task set by themselves (*intention initiation*). The score was based on whether or not the participants initiated the tasks after having written their date of birth on the participant information form (0 = not initiated; 1 = initiated).

3) Hypothesis

According to the hypothesis that success in this phase depends critically on executive functions (i.e., monitoring for the signal for the intended time, inhibiting ongoing activities, switching to the intended action), the TBI patients with impaired executive functions and the old healthy participants were expected to perform worse than the young healthy participants.

3.2.2.6. Intention execution phase

If the participants did not start the tasks after having finished the entire questionnaire, the experimenter prompted them to do so and asked if they could recall when they were supposed to have started the six tasks (which all participants were able to do).

1) Execution of the intention

Finally, *intention execution* was measured by two scores, with the first one, *(a) intention fidelity*, indicating how well participants put their previously formed intention into action (percentage of executable items of the intention that were carried out as planned). The second measure, *(b) self-initiated switching*, indicating overall task performance, was derived by subtracting the number of breaks of the second rule (“You are not allowed to do two sub-tasks (A) and (B) of the same type one after the other.") from the number of subtasks that were started (out of six possible tasks).

2) Hypothesis

Proceeding from the hypothesis that executive functions are of critical importance in this phase of the prospective memory process (i.e., organizing behaviour according to an action plan, inhibiting the work on one subtask, and switching to the next), the TBI patients with impaired executive functions and the old healthy participants were expected to obtain lower scores on both measures than the young healthy participants.

3.2.2.7. End of procedure

After having worked on the complex task for 6 min, the participants filled out the remainder of their participant-information questionnaire and were debriefed.

3.3. Results

3.3.1. Participant characteristics

In Table 2, the TBI patients, the old, and the young control participants are compared for age, gender, verbal intelligence level (as measured by the MWT-B), and for executive functions (as measured by the percentage of possible categories completed of the Wisconsin Card Sorting Test; WCST, Heaton, Chelune, Talley, Kay, & Curtiss, 1993).

Table 2. ***Group Comparison for Demographic Variables and WCST Test Performance***

	TBI (n = 7)		Healthy old adults (n = 21)		Healthy young adults (n = 19)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age (years)	37.86	15.99	70.81	5.87	24.26	4.24
Verbal intelligence	108.83	15.25	119.33	12.17	118.31	15.12
WCST[a]	62.50	27.00	63.00	31.01	92.95	18.76
Gender	1 woman / 6 men		10 women / 11 men		12 women / 7 men	

Note. [a]Percentage of completed categories.

3.3.1.1. Age

An analysis of variance (ANOVA) on age revealed a significant main effect of experimental group, $F(2,44) = 191.46$, $p < .001$. Post hoc comparisons (*Dunnett–T*) showed that the old healthy participants were older than the TBI patients ($p < .001$) and older than the young healthy participants ($p < .001$). The TBI patients were in turn older than the young healthy participants ($p < .001$).

3.3.1.2. Gender

There was a larger proportion of men in the TBI group due to the fact that more men than women experience traumatic brain injuries (Keidel & Poremba, 1998). Furthermore, there was a slightly higher proportion of women in the group of young healthy participants, while in the group of healthy old participants there was an almost equal number of men and women. However, the difference in gender proportion just failed to turn significant, $\chi^2 = 4.916$, $df = 2$, $p = .086$.

3.3.1.3. Verbal intelligence

The TBI group also had a slightly lower verbal intelligence level than the healthy control participants, but it was still at a very high level. The two groups of healthy control participants had a similar verbal intelligence level. However, the ANOVA on the verbal intelligence level did not reveal a significant group difference, $F(2, 43) = 1.393$, $p = .259$.

3.3.1.4. Executive functioning

The healthy young participants completed a higher percentage of categories on the WCST than the TBI patients and the old healthy participants. Both of the latter groups showed a very similar percentage of completed categories on the WCST. An ANOVA revealed a significant difference in the performance of the three experimental groups, $F(2, 38) = 7.029$, $p = .003$. Post hoc (*Dunnett–T*) group comparisons revealed that the TBI group and the old healthy participants had significantly lower scores than the young healthy participants ($p = .035$ and $p = .001$, respectively). The TBI patients with impaired executive functions and the old healthy adults did not differ in their performance in this executive measure.

3.3.2. Complex prospective memory performance

In Table 3, the three experimental groups are compared for the five prospective memory measures: intention formation (i.e., the intention elaboration score previously described), intention retention (i.e., what was retrospectively recalled relative to the previously stated intention), intention initiation (i.e., whether participants initiated the prospective task set after having written their date of birth on the participant information form), and the two intention execution scores: (a) intention fidelity (i.e., how well the intention was executed as planned), and (b) self-initiated switching (i.e., number of subtasks that were started minus number of switching rule breaks).

Table 3. ***Group Comparison for Complex Prospective Memory Performance***

	TBI		Old controls		Young controls	
	M	*SD*	*M*	*SD*	*M*	*SD*
Intention formation	6.14	5.34	9.19	6.44	13.00	4.89
	(n=7)		*(n=21)*		*(n=19)*	
Intention retention	78.34	21.73	82.97	25.66	94.44	16.17
	(n=5)		*(n=15)*		*(n=18)*	
Intention initiation	.14	.38	.33	.48	.95	.23
	(n=7)		*(n=21)*		*(n=19)*	
Intention execution: (a) intention fidelity	43.34	16.05	52.87	26.49	74.30	28.60
	(n=5)		*(n=15)*		*(n=18)*	
Intention execution: (b) self-initiated switching	3.57	1.81	3.05	1.28	4.95	1.13
	(n=7)		*(n=21)*		*(n=19)*	

3.3.2.1. Intention formation

For the intention formation, despite the instruction to do so, 8 participants did not specify in which order they wanted to perform the task, or how much time they planned to spend, or how many items they wanted to complete on each subtask. Consequently, for these participants there were no executable items, and it was, therefore, impossible to calculate their intention retention and their intention fidelity scores. Of these 8 participants, 2 were TBI patients with executive function impairments (28.6 percent of this group), 6 were old healthy adults (33.3. percent of this group) and 1 was a young healthy adult (5.3 percent of this group). The difference in percentage of participants without executable items in the intention was not significant, $\chi^2 = 3.972$, $df = 2$, $p = .137$.

In the following, ANOVAs were carried out on the different prospective memory measures with experimental group (TBI patients, healthy old adults, and healthy young adults) as between-subjects factor. The ANOVA on the intention formation measure revealed a significant main effect of experimental group, $F(2, 44) = 4.389$, $p = .018$. Post hoc comparisons (*Dunnett–T*) confirmed the hypothesized significant difference between the performance of the TBI patients and the performance of the young healthy adults ($p = .009$) as well as the significant difference between the performance of the old healthy adults and the young healthy adults ($p = .039$). The TBI patients with impaired executive functions and the old healthy adults did not differ in their performance in the intention formation phase.

3.3.2.2. Intention retention

Although TBI patients and old adults were on a slightly lower level, there was no significant group effect with regard to intention retention, $F(2, 35) = 1.792$, $p = .182$. All three experimental groups showed very high intention retention scores.

3.3.2.3. Intention initiation

The ANOVA on the intention initiation measure revealed a significant main effect of experimental group, $F(2, 44) = 17.497$, $p < .001$. In accordance with our hypothesis, post hoc comparisons showed that significantly more young healthy adults than old healthy adults ($p < .001$) and than TBI patients with impaired executive functions initiated the task set at the appointed time ($p < .001$). The TBI patients with impaired executive functions and the old healthy adults did not differ in their performance in this phase.

3.3.2.4. Intention execution: (a) intention fidelity

The ANOVA on the intention fidelity scores demonstrated again a significant main effect of experimental group, $F(2, 35) = 4.037$, $p = .026$. Post hoc comparisons revealed a significant difference in the performance of the old adults and the young healthy adults ($p = .030$), and a significant difference in the performance of the TBI patients with impaired executive functions and the young healthy adults, $p = .026$. Again, TBI patients with impaired executive functions and healthy old adults did not differ in their performance.

3.3.2.5. Intention execution: (b) self-initiated switching

Regarding the self-initiated switching score, there was a significant effect of experimental group, $F(2, 44) = 10.732$, $p < .001$. Post hoc comparisons confirmed a significant difference between old and young healthy adults ($p < .001$) and a significant difference between the TBI patients with impaired executive functions and the young healthy adults, $p = .021$. As predicted, the young healthy adults obtained higher scores than the other two experimental groups which did not differ in their performance.

3.4. Discussion

In summary, the study demonstrated that a group of relatively young traumatic brain injury patients with retrospective memory within normal limits but impaired executive functions and a group of healthy old adults obtained significantly lower scores than a group of healthy young controls in the intention formation, intention initiation, and intention execution measures of Kliegel et al.'s (2000) complex prospective memory task. In contrast, all three groups performed well and not significantly different in recalling their previously planned intention. This finding is in line with the two major assumptions of the present study.

First, since it was also demonstrated that TBI patients and healthy old adults performed very similar and worse than the young healthy adults on a classical neuropsychological measure for executive functioning (Wisconsin Card Sorting Test), the data pattern is in line with the proposition that intention formation, initiation, and execution of a complex prospective memory task are related to executive functioning. Moreover, the finding that intention retention was very high (and did not significantly different between the three experimental groups) is consistent with the conclusion that successful management of this prospective memory phase is not largely impaired in TBI and old adults and might (at least mainly) rely on retrospective memory skills. This is in line with data previously reported by Kliegel et al. (2002; see also Martin, Kliegel, & McDaniel, 2003) testing healthy adults.

Second, the healthy old participants showed the same pattern of performance decrements in the complex prospective memory task in comparison to the young controls as the more than 30 years younger traumatic brain injury patients with retrospective memory within normal limits but impaired executive functions. This is the first study to show this kind of result. Since it was also demonstrated that the healthy old participants were as impaired as the TBI patients in comparison to the healthy young adults on an additionally included executive functioning test (WCST), this finding extends earlier, mostly correlational studies on normal aging showing that age-related decline in prospective memory is related to deficits in executive functioning measures (Kliegel et al., 2002, Kliegel, Ramuschkat et al., 2003a, b; McDaniel et al., 1999), and supports the proposal that age-related prospective memory decline might be related to the deterioration of executive functioning.

However, the results must be viewed as preliminary as this study has several limitations. In this study we focussed on the role of retrospective memory and executive functions on the different phases of complex prospective memory. Therefore, other cognitive variables which might also play a role in prospective memory and might also be impaired by aging or traumatic brain injury were not taken into account. For example, speed of processing is a variable that seems to decline in old age (Salthouse, 1996) as well as to be impaired by traumatic brain injury (Madigan, DeLuca, Diamond, Tramontano, & Averill, 2000) and is also thought to be related to prospective memory performance (West & Craik, 2001). Though possible, little is known about the influence of speed of processing on prospective remembering in general. Nevertheless, slower speed of processing might lead to difficulties in initiating the intended action at the right moment and executing it as planned (because the time for execution was limited to 6 min) in the complex prospective memory task. However, intention formation and retention should be spared as for these phases of the complex memory task there were no time limits and, still, the traumatic brain injury patients and the old healthy participants obtained significantly lower scores than the young healthy adults on the, unspeeded, intention formation measure. Moreover, even the time limit for the intention initiation (required time: after answering a question about their date of birth in a questionnaire) was not a very demanding one because the study participants could complete this questionnaire self-paced. Therefore, it seems plausible that the group differences in the intention formation, intention initiation, and intention execution measures of the complex prospective memory task were not mainly caused by potential differences in speed of processing.

Another issue to be discussed is that the phases of the complex prospective memory task might not be totally independent from each other. Consequently, one could claim that if the TBI patients with deficits in executive functioning and the old healthy adults already performed worse than the young healthy adults in the intention formation phase, then their performance in the following phases must be also impaired. Should this be the case, then the finding that the TBI patients with impairments in executive functioning and old healthy adults performed worse than the young healthy adults in the intention initiation and the intention execution phases would no longer exclusively support the assumption that in each of these phases executive functions are needed. However, investigating healthy adults, Kliegel et al. (2000; 2002); Kliegel, Ramuschkat et al.(2003a,b), and Martin et al. (2003) have demonstrated that besides in intention formation executive functions seem to play an additional role in intention initiation and intention execution. Moreover, Kliegel et al. (2000) found that only the performance in the intention execution phase (intention fidelity and self-initiated switching) was associated with the performance in the intention formation phase and with the performance in the intention retention phase (intention fidelity only). Performance in the intention retention and intention initiation phases was not related to performance in earlier phases. In addition, they also reported that a larger amount of variance in the performance in both the intention initiation and intention execution phases could be accounted for by executive functioning measures than by the intention formation or intention retention measures. Consequently, executive functions, at least, seem to play an additional role in each of these phases.

Finally, as the group sizes, particularly the group size of the TBI patients, were small, the power of the statistical analyses was low, particularly challenging the non-significant finding on intention retention. Indeed, the TBI patients and the old healthy adults showed in fact slightly lower intention retention scores than the young adults. Therefore, the TBI patients and the old healthy adults might have had slightly lower retrospective memory for their intention than the healthy young adults.

However, there are several reasons why this power issue does not prevent meaningful interpretation of the present data. First, the possibly lower retrospective memory of the TBI patients and the old healthy participants probably had no or only a small effect on the intention formation, initiation and execution measures. (a) As indicated, all TBI patients at the time of performance had a retrospective memory ability within normal limits (even though two patients probably had experienced a substantial loss due to TBI) (b) Before the participants started to form their action plan, it was made sure that all of them could recall the prospective memory task instruction. (c) Additionally, all participants could remember the instructions and the time for the execution of the intention when questioned at the end of the prospective memory task. (d) Even in TBI patients and old adults, intention retention was at a very high level (around 80%). Thus, also TBI patients and old adults had been able to retrospectively recall most elements of their previously planned intention. However, they still forgot to initiate it more often and executed less of their planned and well recalled intention. (e) Related to the last point, when taking a closer look at the data, there is a larger difference between the intention retention and intention fidelity scores than between the intention formation (as 100% of executable items) and intention retention scores, suggesting that more than poorer intention retention must have lead to the intention execution impairments of the TBI patients and the old healthy adults.

Second, in principal, the reduced power issue applies for all of the statistical analyses. Nevertheless, in all prospective memory phases except intention retention reliable and meaningful group effects were detected. Thus, even if we cannot rule out that there had not been a group difference in intention retention this difference in recalling the exact content of the previously planned complex intention in as many details as possible was very small, at least much smaller than the differences in all other task components, and - as argued above - most probably not responsible for the differential effects we found regarding the formation, initiation, and execution of the intention. Analyzing the power issue more closely, to detect the difference in intention retention on a standard alpha level of .05 with a power of .80, 30 more TBI patients would have been necessary. As we only found 10 TBI patients who fulfilled the inclusion criteria of the present study in a data base of over 500 patients of a major neurological Day-Care-Clinic, we would have to screen more than 1850 prospective patients of this clinic to include those 30 additional patients.

Overall, despite these limitations of the study, the present findings give some new insights and further support to the assumption that executive functions play a role in the intention formation, intention initiation, and intention execution phases of fulfilling a delayed intention. Furthermore, the findings of the study support the notion that age-related prospective memory decline might be associated with the deterioration of executive functioning, although the influence of other variables could not be completely ruled out. In the future, one avenue toward a better understanding of the role of executive functions in prospective memory might be to use (larger) groups of individuals with very selective executive deficits. With regard to practical implications, this study underlines that it is particularly important to support people with prospective memory problems in planning the delayed intention appropriately and in initiating the intended action at the intended time. As studies by Kim, Burke, Dowds, Robinson Boone, and Parks (2000) and Thöne-Otto and Walther (2003) demonstrated, alleviating some of these demands with electronic devices such as palmtop computers or mobile phones might be particularly useful.

4. Studies 2 and 3: Motor Preparatory Processes in Prospective Memory Encoding in Young and Old Healthy Adults

4.1. Study 2: Motor Preparatory Processes in Young Adults[2]

4.1.1. Introduction

Prospective memory has been described as the processes and skills that support the fulfillment of delayed intentions (Ellis & Kvavilashvili, 2000). Delayed intentions are intentions that involve activities that cannot be executed immediately, but have to be postponed until a later time in the future, and thus have to be stored in memory. Ellis (1996) proposed that the representation of a delayed intention in memory should consist of three components: a representation of the intended activity (mental or motor), a representation of the intended execution time (characteristics of a future occasion for intention execution such as certain events, locations, persons, or times), and a representation of the intent itself (decision or readiness to act in the future).

Prospective memory research has mainly focused on the fulfilment of delayed intentions in the form of verbal instructions to perform a certain motor action at a certain time in the future. A typical finding in prospective memory research is that people are able to retrospectively recall the content of such intentions, although many fail to execute them at the intended time. This superior recall of intentions is also seen in old adults and patients with Alzheimer's disease (Maylor, Smith, Della Sala, & Logie, 2002) who often show small (see Henry, MacLeod, Philipps, & Crawford, 2004) or in the latter case severe decrements in free recall for other materials, such as word lists, pictures, or geometric patterns. This finding is not only caused by the simplicity of delayed intentions in the most frequently used prospective memory paradigm (Einstein & McDaniel, 1990). When using a prospective memory paradigm which requires participants to form and later fulfill a complex delayed intention composed of several actions in a specific order, Kliegel and colleagues (Kliegel, Eschen, & Thöne-Otto, 2004; Kliegel, McDaniel, & Einstein, 2000) demonstrated that intention retention was very high and at a similar level for young and old participants.

According to Goschke and Kuhl (1993), the superior retention of delayed intentions in the form of verbal instructions to perform a motor action later in comparison to the retention of other materials can be attributed to a heightened activation level of these intentions in

[2] A similar version of this section has been published as: Eschen, A., Freeman, J., Dietrich, T., Martin, M., Ellis, J., Martin, E., & Kliegel, M. (2007). Motor brain regions are involved in the encoding of delayed intentions: A fMRI study. *International Journal of Psychophysiology*, *64*, 259-268.

comparison to other contents in memory, a phenomenon they called the *intention superiority effect*. In several experiments, Goschke and Kuhl asked participants to encode two pairs of action scripts (i.e., setting a dinner table or dressing up for leaving) for a later recognition test. Each action script consisted of four component actions. After encoding one pair of action scripts to a fixed learning-criterion, the participants were told that they later had to execute one of the scripts. After encoding of the second pair of action scripts to the learning-criterion, the participants were told that they later had to observe one of the scripts being performed by the experimenter and register mistakes. The other, neutral, action script of each pair had to be remembered for the recognition test only. Immediately after the execution or observation instructions, a recognition test for words from both action scripts of one pair followed. Finally, after the recognition test, participants executed or observed the scripts. There was no difference in recognition latencies between words from the to-be-observed action script and from the other neutral action script of this pair. However, there were shorter recognition latencies for words from the to-be-executed action script in comparison to the words from the neutral action script of this pair, thus indicating the higher accessibility in memory of delayed intentions in the form of verbal instructions to perform a motor action. Since the action scripts in all conditions were learned to the same criterion, Goschke and Kuhl argued that the higher accessibility of delayed intentions to perform an action in the future is attributable to the intent-to-act-component of these intentions.

These findings have been extended by Marsh, Hicks, and Bink (1998) in experiments using a lexical-decision task instead of a recognition task and by Freeman and Ellis (2003a). Freeman and Ellis (2003a), however, asked participants to encode one set of simple actions for later enactment and another for later verbal report. After the encoding phase, participants were informed which action set they had to enact or report later. After the recognition test, Freeman and Ellis asked participants to perform the actions that they had encoded for later enactment as well as to report the actions that they had encoded for later verbal report. Furthermore, Freeman and Ellis (2003a) could demonstrate the intention superiority effect when they asked participants directly, in the beginning of the experimental procedure, to encode one set of simple actions for later enactment and the other for later verbal report. Using this paradigm, Freeman and Ellis (2003b) found the intention superiority effect also in old participants, perhaps giving an explanation for the age invariance in intention retention reported by Kliegel and colleagues.

Moreover, Freeman and Ellis (2003a) found a higher accessibility in memory of to-be-enacted actions in comparison to to-be-reported actions when the performance or verbal report of the encoded actions had to be initiated by the participants themselves at a specific time in the future as in a classical prospective memory paradigm, whereas in Goschke and Kuhl's original paradigm the execution of the to-be-executed action script was initiated at a previously unspecified time by the experimenter. Furthermore, whether participants had to initiate the performance or the verbal report of the actions by themselves or were initiated by the experimenter had no influence on the general accessibility of the self-initiated actions, regardless of whether they were intended for later verbal report or enactment, and on the relative advantage of later to-be-performed actions. This suggest that the higher activation of delayed intentions in the form of verbal instructions to perform an action in the future is independent from certain characteristics of the intended execution time, such as specification of time or mode of execution initiation. This indicates again the importance of the intent-to-act-component for the intention superiority effect.

Findings by Koriat, Ben-Zur, and Nussbaum (1990) give further support for the intention superiority effect. Koriat and colleagues asked participants to encode unrelated verb-noun phrases either for later enactment or for later verbal report. Recall was better for phrases participants expected to enact regardless of the actual recall mode (enactment or verbal report). However, Brooks and Gardiner (1994) failed to demonstrate a recall advantage for to-be-performed in comparison to to-be-reported actions. Engelkamp (1997) attributed the differential findings to design differences, because he could find a recall advantage for to-be-performed actions compared to to-be-reported actions in a between-subjects design that had been used by Koriat and colleagues (1990), but not in a within-subjects design that had been employed by Brooks and Gardiner (1994). In contrast, Jahn and Engelkamp (2003) reported superior recall for to-be-enacted actions over to-be-reported actions in a between- as well as in a within-subjects design, indicating that this effect is more robust than earlier findings suggested.

Freeman and Ellis (2003a) proposed that the higher accessibility of delayed intentions in the form of verbal instructions to perform an action later as compared to other memory contents might actually reflect the translation of the verbal information about the intended action into a motor format with the encoding of the intent-to-act component. More specifically, in comparison to the encoding of verbal instructions to later report or observe actions, additional sensorimotor information (e.g. its force, direction, duration) about the intended action is generated in preparation for later execution, thus enhancing memory. Therefore, Freeman and Ellis proposed that the finding of a higher accessibility of delayed intentions in the form of verbal instructions to later perform actions in comparison to verbal instructions to later observe, or report actions could more accurately be interpreted as an *action superiority effect*.

Support for the hypothesis that delayed intentions in the form of verbal instructions to enact an action in the future may be translated into a motor format for later execution comes from findings that their higher accessibility in memory is lost when a secondary motor task is introduced at the same time the intent to act is encoded, thus presumably disturbing the concurrent generation of sensorimotor information about the to-be-enacted action. Freeman and Ellis (2003a) asked participants to encode two pairs of action sets. The participants were informed that they had to learn both sets of each pair for a subsequent recognition test and additionally had to either enact or verbally report one set of each pair after the recognition test. Which set of a pair they had to recall and in which recall mode (verbal report or enactment), they were not to be told until after encoding of each pair. Half of the participants were asked to immediately start a simple verbal task (counting forward from 1 to 10) after these instructions for both pairs of action sets. The other half of the participants were asked to immediately undertake a simple motor task (making repetitive circular movements with both hands) after these instructions for both pairs of action sets. In both groups, the verbal or motor tasks were stopped after 90 s. Subsequently, recognition for actions from both action sets of one pair was tested. Finally, participants had to enact or report the appropriate action set of one pair. Shorter recognition latencies for to-be-performed actions than for to-be-reported actions could still be found when the verbal task was started just after participants were informed about which action set they had to enact later. However, there was no longer an advantage for later to-be-performed actions when a motor interference task was introduced immediately after these instructions. Brandimonte and Passolunghi (1994) also found, in a prospective memory paradigm, that the timely execution of delayed intentions requiring a motor response (key-press response to a specific word in a subsequent short-term memory task) was disturbed compared to a no-delay-condition when participants had to perform a short undemanding motor task after the prospective memory task instructions, but not when the short delay period was filled with an undemanding verbal task. Presumably, the motor task interfered with preparatory motor operations for later action execution.

Further data by Freeman and Ellis (2003a) suggest that during encoding of delayed intentions in the form of verbal instructions to perform an action, the verbal information is translated into a motor format for later action execution, thus enhancing memory through the provision of rich sensorimotor information. When to-be-performed and to-be-reported actions were motorically (enacted during encoding) rather than verbally encoded (read during encoding), there were no shorter recognition latencies for to-be-performed versus to-be-reported actions. This indicates that there may be an overlap between processing when actions are executed and verbally encoded for future action execution, probably in preparatory motor operations.

Starting from Freeman and Ellis` (2003a) assumption that during the encoding of delayed intentions in the form of verbal instructions to perform an action later motor preparatory operations occur for the later to-be-enacted actions, the aim of our study was to use functional magnetic resonance imaging (fMRI) to demonstrate that motor brain regions are differentially activated during the verbal encoding of simple actions intended for later enactment in contrast to the verbal encoding of similar actions for later verbal report.

In the present study, all to-be-enacted actions were encoded for later performance with the right arm only. Findings by Nyberg et al. (2001) suggest that the left primary motor/premotor cortex, the right midcingulate, and left somatosensory cortex are likely candidate regions for the differential brain activation during the encoding of actions for later enactment with the right arm versus later verbal report. Using positron emmission tomography (PET), Nyberg et al. (2001) found these brain regions were differentially activated when simple actions were enacted as well as imagined to be enacted with the right hand during encoding in contrast to the purely verbal encoding of simple actions, implying that these brain areas are involved in covert preparatory motor operations for enactment with the right arm.

Several studies (Leynes, Marsh, Hicks, Allen, & Mayhorn, 2003; West & Ross-Munroe, 2002) using event-related brain potentials (ERPs), however, indicate that more anterior non-motor brain regions in the frontal lobes may play a role in the verbal encoding of actions intended for later enactment. West and Ross-Munroe (2002) reported a frontal-polar slow wave to be the neural correlate of the encoding of delayed intentions requiring a motor response at a prespecified execution time. Leynes et al. (2003) employing a similar paradigm to the one used in the present study (apart from using actions that could be enacted with one or both arms, not only with the right arm), found that ERPs elicited by actions that were encoded for later enactment were particularly more positive at right frontal electrodes than the ERP activity elicited by actions encoded for a subsequent non-motor memory test. Since fMRI is a more suitable method for studying the anatomical localization of neural activity than ERP, the present study will help to clarify whether more anterior non-motor or more posterior motor frontal brain regions such as the primary motor or premotor areas are differentially activated during the verbal encoding of actions intended for later enactment.

In addition to the conditions of verbal encoding of actions for later execution and later verbal report, we also included a baseline condition of verbal encoding of abstract verbs for later verbal report in the present study. This was done to test whether the semantic motor information inherent in action verbs in contrast to abstract verbs also differentially activates motor brain regions and whether these are other brain regions than those differentially activated when contrasting the verbal encoding of actions intended for later enactment with that of actions for later verbal report. For example, Hauk, Johnsrude, and Pulvermüller (2004) reported that when their participants read actions words referring to face, arm, or leg actions, brain regions in the primary motor cortex were differentially activated that were adjacent or overlapping with brain areas activated by actual movements of the tongue, the fingers, or the feet.

4.1.2. Method

4.1.2.1. Participants

Thirteen healthy young native German speakers participated in the study. Three participants had to be excluded from the data analysis because they enacted action verbs during encoding despite being instructed differently. The mean age of the remaining 6 women and 4 men was 24.1 years (*SD* = 4.10). They were all right-handed as assessed with the Edinburgh Inventory (Oldfield, 1971). None of the participants reported any neurological or psychiatric disorders or substance use known to affect brain function nor any sensory impairments interfering with study participation in a screening questionnaire. They all had normal or corrected to normal vision. All participants met fMRI safety requirements and gave their written informed consent. They received course credit or payment for their study participation.

4.1.2.2. Procedure

At the beginning of the experimental session, participants were told that the aim of the present study was to investigate which brain regions are active when actions are learned and recalled in different ways. Participants were informed with written and oral instructions that the study consisted of three parts. In the first part, the encoding phase, they were to learn action words for two different types of later recall (i.e., later verbal report or later enactment). In the second part, the recognition phase, they were to see all learned actions again as well as the same number of new actions and were to decide which actions they had seen before and which not. In the last part, the recall phase, they would have to recall the learned action words from the first phase and to execute them or name them to the experimenter. The encoding and recall phases were demonstrated and exercised with a practice task. Subsequently, the participants completed the encoding phase and the recognition phase inside the fMRI scanner, in two separate runs. The recall phase took place outside of the scanner. Afterwards, participants were questioned about encoding strategies and then completed a range of neuropsychological tests.

4.1.2.3.Tasks

The encoding phase consisted of three conditions. In the *actions for enactment condition (ENACT)*, the participants saw action words that they were to encode for later enactment with the right arm. In the *actions for verbal report condition (REPORT),* the participants saw action words that they were to encode for later verbal report. In the *abstract verbs for verbal report condition (ABSTRACT),* the participants saw abstract verbs that they were to encode for later verbal report. Actions and abstract verbs were matched for length. All actions and abstract verbs consisted of one word. All actions were movements that could be enacted with one arm such as write, pour, or stab. Abstract verbs, such as think, accomplish, or decide, were not associated with specific movements. All words were presented at fixation on a black background for 4 s with an interstimulus interval of 2 s. Actions that participants had to encode for later enactment were presented in yellow colour, actions and abstract verbs that they had to encode for later verbal report were presented in turquoise colour. As pre-tests had shown that participants had problems distinguishing the three quite similar encoding conditions, they were not informed about the difference between the REPORT and ABSTRACT conditions. They were only told that they would have to encode yellow actions for later enactment with the right hand and turquoise actions for later verbal report. Participants were asked to read the words repeatedly while encoding. In the scanner, before the words for encoding were shown, the following short version of the instructions was presented to the participants for 10 s: “Turquoise words: read them repeatedly and report them later! Yellow words: read them repeatedly and execute them later!”. Afterwards, change of encoding mode (encoding for later verbal report versus encoding for later enactment) was indicated by colour of words only.

For fMRI data acquisition, a block-design was adopted since the main aim of the study was to find differences in brain activation between two different encoding modes (encoding for later enactment versus encoding for later verbal report). Additionally, it was assumed that quick changes between the different encoding modes as in an event-related design (i.e., encoding of one action for later verbal report, the next for later performance, the next again for later verbal report etc.) would be too demanding for participants and they would therefore not always be able to choose the instructed encoding mode. In each condition, 24 verbs were shown in 3 blocks of 8 words. The 9 blocks were presented to all participants in the following order: REPORT, ABSTRACT, ENACT, REPORT, ENACT, ABSTRACT, ENACT, ABSTRACT, and REPORT. This order of blocks was chosen to present participants a quite regular change between different encoding modes. A schematic illustration of the experimental procedure of the encoding phase can be seen in Figure 2.

Blocks

Inst.	REPORT	ABSTRACT	ENACT	REPORT	ENACT	ABSTRACT	ENACT	ABSTRACT	REPORT	
0s	10s	58s	106s	154s	202s	250s	298s	346s	394s	442s

Trials in blocks

verb1	ISI	verb2	ISI	verb3	ISI	verb4	ISI	verb5	ISI	verb6	ISI	verb7	ISI	verb8	ISI	
0s	4s	6s	10s	12s	16s	18s	22s	24s	28s	30s	34s	36s	40s	42s	46s	48s

Scans for trial and ISI

verb 1		ISI	verb 2
scan 1	scan 2	scan 3	scan 4
0s	2s	4s	6s

***Figure 2*. Schematic Illustration of the Experimental Procedure of the Encoding Phase.**

Note. Inst. = Instruction. Gray colour of block indicates presentation of verbs in turquoise colour and white colour indicates presentations of verbs in yellow colour.

In the recognition phase the participants were shown 144 verbs: those 72 verbs they had encoded in the encoding phase and 72 new verbs. As in the encoding condition, 48 of the new words were action words that could be enacted with one arm and 24 were abstract verbs. Again, all words were matched for length. The participants had to indicate by key press whether they had already learned a word in the encoding phase or not (left key for learned words, right key for new words). The words were presented at fixation on a black screen in white colour for variable durations between 6 and 10 s and with variable interstimulus intervals between 0 to 2 s each, as an event-related design for fMRI data acquisition was applied here. Before the start of the recognition test, the following instruction was presented to the participants for 10 s: "Now 144 words will be presented to you: 72 you have just learned and 72 are new. Decide for every word if you have learned it or not. If yes, then please press the left key, if no, then please press the right key!". Because of technical problems, we could not collect enough recognition data for statistical analysis, so we cannot report these data here.

In the recall phase participants were asked to enact those actions with the right arm and to verbally report those words that they had encoded for the respective recall mode. Subsequently, they were asked about strategies they had employed during the encoding of actions for later enactment and during the encoding of verbs for later verbal report.

Finally, a battery of neuropsychological tests, such as the verbal intelligence test Mehrfachwahlwortschatztest B (MWT-B; Lehrl, 1977) and tests for the immediate and delayed free recall of two short stories (the subtests Logical Memory I and II of the Wechsler Memory Scale - Revised German Version, WMS-R; Härting et al., 2000), were conducted. Furthermore, the participants were asked to rate the frequency of their everyday prospective and retrospective memory failures in the Prospective and Retrospective Memory Questionnaire (PRMQ; Crawford, Smith, Maylor, Della Sala, & Logie, 2003). For all the neuropsychological tests as well as the PRMQ normative data is available.

4.1.2.4. Apparatus

The fMRI measurements were carried out on a 3 T scanner (Signa EXCITE, General Electrics, U.S.A.). A head coil open at the front was used. A mirror was attached to the coil so that the participants were able to see a transparent screen located at the back of the scanner. To minimize head movements within the coil, the participants' heads were stabilized using foam padding.

The stimuli were projected onto the translucent screen using a video projector (Lite Pro 720, Infocus, The Netherlands). They were presented with a PC via Presentation® software (Neurobehavioral Systems, U.S.A.). In order to synchronize stimulus presentation with fMRI scanning a trigger signal was used. In the recognition phase, participants' responses were collected with a response box (Lumina LP-400, Cedrus Corporation, U.S.A.) and recorded with Presentation software on the PC.

4.1.2.5. Image acquisition protocol

Functional magnetic resonance image acquisition was performed using gradient echo planar imaging (repetition time, TR = 2 s; echo time, TE = 32 ms; field of view, FOV = 96 x 96 mm^2; flip angle = 50°; matrix size = 128 x 128 x 26; voxel size = 1.8 x 1.8 x 1.8 mm^3; 26 slices parallel to an imagery line connecting the anterior and posterior commissure covering the whole brain; slice thickness = 3.8 mm; no interslice gap; interleaved slice acquisition). For the encoding phase, a total of 225 scans were acquired. Three-dimensional high-resolution anatomical images of the entire brain were also obtained, using a T1-weighted gradient echo pulse sequence (TR = 13 ms; FOV = 256 x 256 mm^2; slice thickness = 1 mm; matrix size = 256 x 256).

4.1.2.6. fMRI data analysis

The fMRI data were analysed using Statistical Parametric Mapping (SPM2, Wellcome Department of Cognitive Neurology, UK). The first 5 scans (acquired during instruction presentation) were discarded to allow for steady-state magnetization. The remaining images were realigned and normalized to the standard brain Montreal Neurological Institute (MNI) space (EPI-template), using a voxel size of 2 x 2 x 2 mm^3 and being warped in Y-space. Each normalized scan was smoothed with a 6 mm full-width at half maximum isotropic Gaussian kernel. For each participant, the functional data to all stimuli of the encoding phase were entered into a single design matrix, in which the start and end time of each block of the three different encoding conditions was specified in scan number. Individual statistical maps for each encoding condition were determined by applying the general linear model (settings: high pass filter: 128, low pass filter: hrf, no global scaling, no corrections for serial correlations) and by defining each of the three conditions as a predictor that assumed the value of 1 for its respective volumes and 0 for all other volumes. The contrast images of each subject and condition were entered into a second level random effects within-subjects ANOVA with encoding condition as within-subject factor (with nonsphericity correction replicated over subjects and correction for correlated repeated measurements). This procedure was adopted to calculate the significant variability induced by each encoding condition in relation to the total variability over subjects (Henson & Penny, 2005). At the second level, we contrasted the brain activity during the encoding of actions for later enactment with that during the encoding of actions for later verbal report (ENACT-REPORT) and the brain activity during the encoding of actions for later verbal report with that during encoding of abstract verbs for later verbal report (REPORT-ABSTRACT). The differentially activated brain regions reported for the ENACT-REPORT contrast had been estimated with a non-adjusted p-level of < 0.0001 and had a minimum number of 13 voxels ($p = 0.047$). For the REPORT-ABSTRACT contrast, we report differentially activated brain areas estimated with a non-adjusted p-level of < 0.001 with a minimum number of 28 voxels ($p = 0.047$). The MNI coordinates of activated clusters were transformed into the Talairach coordinates with the MNI2TAL tool written by Matthew Brett. The activated brain areas were identified using the Talairach Daemon (University of Texas, U.S.A.).

4.1.3. Results

4.1.3.1. Behavioural data

In Table 4, the recall performance of the participants for the three different encoding conditions can be seen. Generally, recall performance was rather low (mean recall of 17.6 of 72 encoded words, i.e., 24.4%) and varied greatly between participants ($SD = 12.88$). There was a trend for better recall performance in the ENACT as compared to the recall performance in the other two encoding conditions. However, in a repeated measures ANOVA with encoding condition as within-subjects variable, the effect of encoding condition on recall performance failed to reach significance, $F(2, 18) = 2.019$, $p = .162$. In planned paired t tests, the differences in recall performance between the ENACT and REPORT conditions ($t(9) = -1.230$, $p = .250$) and between the REPORT and ABSTRACT conditions ($t(9) = -.429$, $p = .678$) were not significant. However, there was a significant difference in recall performance between the ENACT and ABSTRACT conditions, $t(9) = -2.909$, $p = .017$.

Table 4. ***Recall Performance for the ENACT, REPORT, and ABSTRACT Encoding Conditions***

		ENACT	**REPORT**	**ABSTRACT**	∑
Number of verbs recalled	*M*	7.10	5.50	5.00	17.60
	SD	4.12	6.10	3.53	12.88

Note. ENACT = Actions for later enactment. REPORT = Actions for later report. ABSTRACT = Abstract verbs for later report.

For the encoding of actions for later enactment (ENACT), all participants reported that they either imagined themselves or another person executing the actions, or both alternately. For the encoding of actions and abstract verbs for later verbal report (REPORT, ABSTRACT), 4 participants stated that they tried to link the verbs semantically together (1 by similarity, 1 formed a story, and 2 formed a film script), 2 participants reported that they tried to decide whether it was possible to enact the verbs with one arm or not, and 4 participants said that they did not use any specific encoding strategy.

The verbal intelligence level of the participants (as measured by the MWT-B) was average (mean *IQ* = 105.5, SD = 8.25). The performance of the participants on an immediate and on a delayed free recall test for two short stories (as measured by the subtests Logical Memory I and II of the WMS-R) was in the upper average to superior range (mean *PR* = 78.8, *SD* = 22.21 and mean PR = 84.20, *SD* = 20.12). In addition, the participants reported an average frequency of everyday retrospective (mean *T* = 58.20, *SD* = 4.64) and prospective memory failures (mean *T* = 55.60, *SD* = 6.92) in the PRMQ.

4.1.3.2. fMRI data

Brain regions more activated during the encoding of actions for later enactment with the right arm in comparison to the encoding of actions for later verbal report (ENACT-REPORT) can be seen in Table 5 and Figure 3. The higher activated brain regions during ENACT were all located in the left hemisphere, i.e., the postcentral gyrus (BA 2), the precuneus (BA 7), the posterior superior frontal gyrus (BA 6), the posterior middle temporal gyrus (BA37/39), the posterior middle frontal gyrus (BA 6), and the inferior parietal lobule (BA 40).

There was only a region in the right posterior superior frontal gyrus (BA 6) more activated during the encoding of actions compared to that of abstract verbs for later verbal report (REPORT-ABSTRACT, see also Table 6 and Figure 4).

Table 5. ***Differentially Activated Brain Regions During Encoding of Actions for Later Enactment in Comparison to Encoding of Actions for Later Verbal Report (ENACT-REPORT)***

Anatomical region	BA	Talairach coordinates			Z	k_E
		x	y	z		
Left postcentral gyrus	2	-57	-29	38	4.90	236
Left precuneus	7	-16	-54	52	4.89	74
Left superior frontal gyrus	6	-20	7	60	4.78	155
Left middle temporal gyrus	39/37	-55	-62	9	4.63	176
Left inferior parietal lobule	40	-48	-52	53	4.32	64
Left middle frontal gyrus	6	-26	-10	37	4.21	69

Note. BA = Brodmann Area. Z = Z score of significant activated clusters. k_E = cluster size.

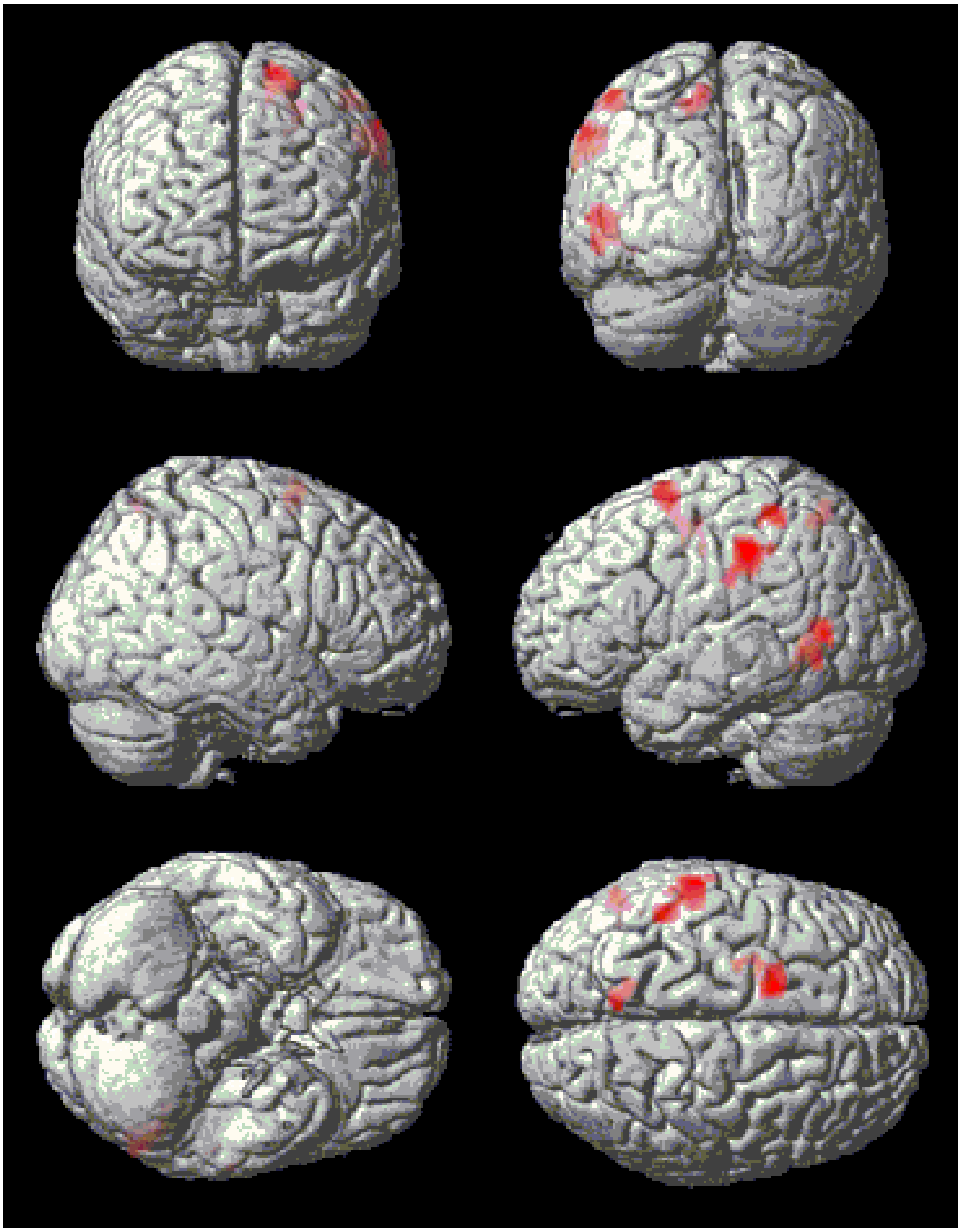

Figure 3. **More Highly Activated Brain Regions During the Encoding of Actions for Later Enactment versus Actions for later Verbal Report (ENACT-REPORT).**

*Note***.** 1st row: Front and back view. 2nd row: Right and left side. 3rd row: Bottom and top view.

Table 6. ***Differentially Activated Brain Regions During Encoding of Actions versus Abstract Verbs for Later Verbal Report (REPORT-ABSTRACT)***

Anatomical region	BA	Talairach coordinates			Z	k_E
		x	y	z		
Right superior frontal gyrus	6	12	-1	64	3.83	74

Note. BA = Brodmann Area. Z = Z score of significant activated clusters. k_E = cluster size.

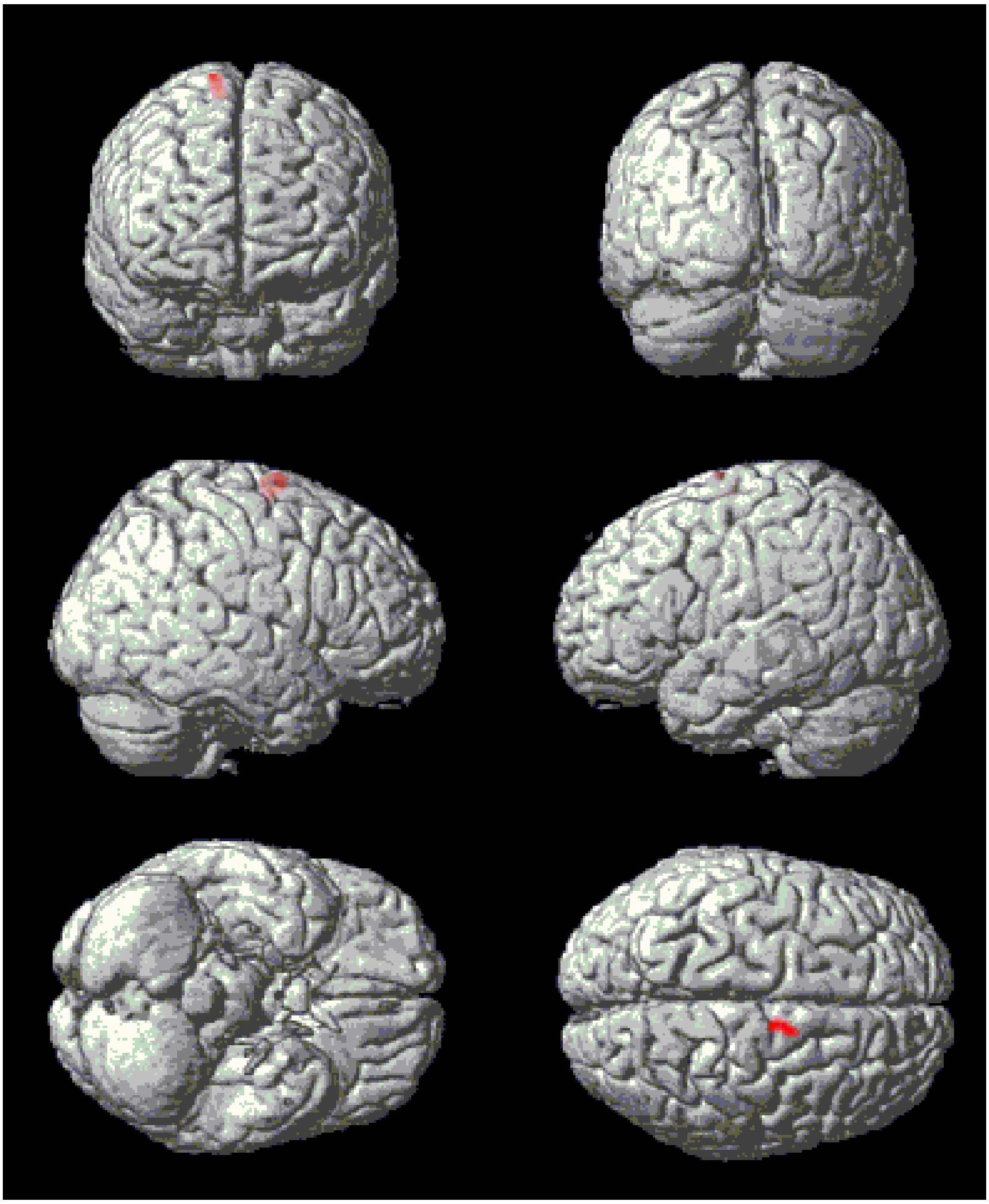

Figure 4. **More Highly Activated Brain Regions During the Encoding of Actions versus Abstract Verbs for Later Verbal Report (REPORT-ABSTRACT).**

Note. 1st row: Front and back view. 2nd row: Right and left side. 3rd row: Bottom and top view.

4.1.4. Discussion

The main aim of the present study was to demonstrate that motor brain regions are differentially activated during the verbal encoding of simple actions intended for later enactment in contrast to the verbal encoding of similar actions for later verbal report. We found that during the verbal encoding of actions intended for later enactment with the right arm in comparison to the verbal encoding of actions for later verbal report following regions in the left hemisphere were more activated: the postcentral gyrus (BA 2), the left precuneus (BA 7), the posterior superior frontal gyrus (BA 6), the posterior middle temporal gyrus (BA 39/37), the posterior middle frontal gyrus (BA 6), and the inferior parietal lobule.

The more highly activated brain region in the left posterior postcentral gyrus (BA 2) corresponds to the left somatosensory cortex that is thought to be involved in proprioception and, therefore, in execution of right hand movements. Accordingly, Naito et al. (2005) reported the left posterior postcentral gyrus (BA 2) to be activated when illusionary right hand movements were elicited by tendon vibration. Grezes and Decety (2001) conducted a meta-analysis on brain regions involved in execution, mental simulation, observation, and verbalization (i.e., action verb generation associated with a manipulable object) of hand movements as determined by whole brain fMRI and PET imaging studies on healthy volunteers. They included 8 studies on execution, 6 studies on mental simulation, 8 studies on observation, and 8 studies on verbalization of hand movements. According to their meta-analysis, the left somatosensory cortex was activated in studies on execution of hand movements only. However, Oouchida and colleagues (2004) found that passive observation of an experimenter's right hand movements activated regions in the left postcentral gyrus (BA 2) that were also activated when the participants themselves performed movements with their right hands, pointing to the role of this brain region also in the observation of right hand movements. Furthermore, Nyberg and colleagues (2001) found the left somatosensory cortex differentially activated when simple actions were enacted as well as imagined to be enacted with the right hand during encoding in contrast to the purely verbal encoding of simple actions.

Activations in the left precuneus (BA 7) were in Grezes and Decety's meta-analysis mainly found in studies focused on observation of hand movements. Additionally, the left precuneus has been differentially activated while imagining in contrast to executing finger-tapping movements with the right hand (Hanakawa et al., 2003). Moreover, Astafiev and colleagues (2003) found the left precunues activated during preparation for pointing movements to visual cues with both the right and left index finger in contrast to preparation for attending or looking at visual cues, indicating an involvement of the left precuneus in motor preparation.

The areas in the left posterior superior frontal gyrus (BA 6) and the left posterior middle frontal gyrus (BA 6) correspond to the left dorsal and ventral premotor cortex, respectively (Picard and Strick, 2001). In Grezes and Decety’s meta-analysis, the left dorsal premotor cortex was activated in the majority of studies on mental simulation and in approximately half of the studies involved in execution and observation of hand movements. The left ventral premotor cortex has only been found to be activated in the majority of studies on verbalization and mental simulation of hand movements. Additionally, the left dorsal premotor cortex has been found to be involved in motor preparation. It was differentially activated during execution of complex as compared to simple sequential finger movements, for movements with both hands (Haaland et al., 2004). Moreover, Astafiev and colleagues (2003) found the left dorsal premotor cortex in addition to the left precunues activated during preparation for pointing movements with both the right and left index fingers in contrast to preparation for attending or looking at visual cues. The left ventral premotor cortex is also involved in preparation of hand gestures as it was activated in a delay before hand gesture execution (Fridman et al., 2006). Futhermore, when participants had to observe guitar chords played by guitar player for later imitation, the ventral premotor cortex was active (Buccino et al., 2004). In contrast, during a pause before execution of the observed chords, the dorsal premotor cortex became more active, indicating again its role in motor preparation. Furthermore, Nyberg et al. (2001) found the left premotor cortex differentially activated when simple actions were enacted as well as imagined to be enacted with the right hand during encoding in contrast to the purely verbal encoding of simple actions.

The left posterior temporal gyrus (BA 39/37) has been found by Grezes and Decety to be activated in studies on observation and verbalization of hand movements only. Moreover, the left posterior middle temporal gyrus seems to be involved in the retrieval of motor-related knowledge about overlearned meaningful actions. Accordingly, semantic decisions on action words relative to non-actions words (Kable et al, 2001), whether heard or read (Noppeney et al., 2005), or the observation of meaningful in comparison to meaningless actions for later imitation (Decety et al., 1997) elicited differential brain activity in the left posterior middle temporal cortex.

Finally, the left inferior parietal lobule (BA 40) was activated in all studies included on mental simulation of hand movements and in the large majority of studies included on observation of hand movements in Grezes and Decety’s meta-analysis. This area has also been reported to be involved in motor preparation. It was also activated during preparation of pointing movements of fingers of both hands in Astafiev and colleagues' study, during the delay before gesture execution in Fridman and colleagues' study, and during execution of complex in contrast to simple finger movements with both hands in Haaland et al.'s study. Futhermore, the left inferior parietal lobule seems also to be involved in accessing knowledge about actions. It was differentially activated when participants heard sentences describing actions performed with mouth, hands, or legs in comparison to abstract sentences (Tettamanti et al., 2005).

In summary, during the verbal encoding of actions for later enactment in contrast to encoding of actions for later verbal report, we found differential activation in a network of left motor brain regions mainly involved in covert motor tasks concerning hand movements, such as mental simulation, observation, verbalization, and retrieval of knowledge about hand movements. Moreover, many of these brain regions have been found to be activated during preparation delays for later hand movement execution. This finding is in line with Freeman and Ellis' (2003a) assumption that during the encoding of delayed intentions in the form of verbal instructions to perform an action in the future, preparatory motor operations occur for the later to-be-enacted actions.

Contrary to earlier ERP studies on the verbal encoding of actions intended for later enactment (Leynes et al., 2003; West & Russ-Monroe, 2002), we did not find areas in the more anterior non-motor prefrontal lobe be more activated during the verbal encoding of actions for later enactment in comparison to the verbal encoding of actions for later verbal report. This might be mainly attributable to the higher sensitivity for anatomical location of fMRI in contrast to ERP. However, there were also differences in the actions to be encoded (present study: actions to be enacted with the right arm; in Leynes et al.: actions to be enacted with either one or both arms; West et al.'s study: letters indicating which key to press at a keyboard with the left index or middle finger), and in the data included in the statistical analysis (present study: data from all actions; ERP studies: data only from actions subsequently correctly memorized or executed).

We also contrasted verbal encoding of actions to that of abstract verbs for later verbal (REPORT-ABSTRACT). This was done to test whether the semantic motor information inherent in action verbs in contrast to abstract verbs also differentially activates motor brain regions and whether these are other brain regions than those differentially activated during the verbal encoding of actions intended for later enactment with that of actions for later verbal report (ENACT-REPORT). In this contrast, only the right posterior superior frontal gyrus (BA6) was more highly activated.

This area corresponds to the right dorsal premotor cortex. In Grezes and Decety's (2001) meta-analysis, it has been activated in studies on execution, simulation, and observation on hand movements. This indicates that some motor processing takes place during verbal encoding of actions in contrast to abstract verbs for later verbal report. However, this brain region is normally not involved in action semantics. It is possible that the present results are not in line with previous findings on action semantics because the participants did not notice the difference between the encoding conditions of verbal encoding of action versus abstract verbs for later verbal report. They were not informed about the difference between those two encoding conditions. Both types of verbs appeared in the same colour and participants were instructed to encode actions with one colour for later verbal report and actions in another colour for later enactment.

There was no overlap between the differentially activated brain regions in the REPORT-ABSTRACT and the differentially activated brain regions in the ENACT-REPORT contrasts. Consequently, those brain regions we found to be more highly activated during the verbal encoding of actions intended for later enactment as opposed to that of actions for later verbal report seemed to be specifically involved in the encoding of actions requiring a later motor response and are not only related to higher demands on semantic retrieval of action-related knowledge about to-be-enacted in contrast to to-be-reported actions.

An important issue to be discussed is whether the brain regions we found to be more activated during encoding of actions intended for later enactment in contrast to that of actions for later verbal report are only related to the imagery of the later to-be-enacted actions. All participants of our study reported that they had imagined themselves or another person enacting the actions during the verbal encoding of actions for later enactment, whereas they stated to have used more semantic or no specific encoding strategies during the encoding of actions and abstract verbs for later verbal report. Additionally, we found brain regions mainly implicated in mental simulation and observation of actions to be higher activated during verbal encoding of actions for later enactment in contrast to that of actions for later verbal report.

Using PET, Decety and colleagues (1997) contrasted the brain activity while participants watched videos of actions enacted with both arms or hands for later imitation to the brain activity when participants watched similar actions for later recognition. Accordingly, the encoding of actions for later enactment could be established while at the same time imagery of these actions could probably be suppressed due to their visual presentation. Decety and colleagues (1997) found similar regions in the left posterior superior frontal gyrus and the left precuneus to be more activated during the encoding of actions for later enactment in contrast to the encoding of actions for later recognition to the ones reported here for the verbal encoding of actions for later enactment in comparison to the verbal encoding of actions for later verbal report. In addition, when participants had to observe guitar chords played by guitar player for later imitation, the ventral premotor cortex was active (Buccino et al., 2004). Therefore, it seems as if the left precuneus, the left dorsal premotor cortex, and the left ventral premotor cortex might be involved in the encoding of actions for later execution, regardless of the induction of enactment imagery during encoding.

A limitation of this study is that we could not clearly demonstrate the higher accessibility of to-be-enacted actions in contrast to to-be-reported verbs in subsequent recall performance. However, there was a trend for better recall performance for to-be-enacted actions in comparison to to-be-verbally reported verbs, although only the difference between the later to-be-enacted actions and the later to-be-reported abstract verbs was significant. Nevertheless, maybe this effect was masked by the altogether high memory load of 72 verbs during the encoding phase and a great retroactive interference caused by the additionally presented 72 new similar verbs in the subsequent recognition phase. In contrast to the normal to superior performance of the participants on an immediate and on a delayed free recall test for two short stories and their reported average frequency of everyday retrospective and prospective memory failures, their recall performance for actions and abstract verbs in the experimental task was rather low. Recall performance of actions encoded for later enactment and later verbal report has been found to decrease with higher number of words (Brooks & Gardiner, 1994) and with more retrospective interference caused by a within-subjects in contrast to a between-subjects design (Jahn & Engelkamp, 2003). Engelkamp (1997), using a comparable amount of words to be encoded in a within-subjects design, found a similar low recall performance and also failed to demonstrate significance for the recall advantage of to-be-enacted actions in contrast to to-be-reported actions. However, the fMRI technique demands participants to engage in longer periods of experimental tasks to acquire meaningful data, so it will be difficult to circumvent the problem of high memory load and within-subject design in future fMRI studies. Additionally, with only 10 participants, the power of the statistical analyses was rather low.

It should also be noted that participants were asked to encode actions for later enactment with the right arm only. Therefore, it is unclear whether the verbal encoding of actions intended for later enactment in contrast to the verbal encoding of actions for later verbal report activates generally motor brain regions predominantly in the left hemisphere or specifically on the contralateral side of the arm they are later executed with. Consequently, in future studies it would be interesting to ask participants to verbally encode actions for later enactment with both the right and the left arm.

In summary, we found brain regions known to be involved in covert motor preparation differentially activated during the verbal encoding of actions intended for later enactment in contrast to the verbal encoding of actions for later verbal report. Furthermore, there was no overlap between brain regions differentially activated during verbal encoding of actions intended for later enactment as compared to that of actions for later verbal report with those brain regions that were differentially activated during verbal encoding of actions as compared to abstract verbs for later verbal report. This suggests that during the verbal encoding of actions for later enactment not only more semantic information inherent in the action words is retrieved, but rather preparatory motor operations take place. Therefore, our findings support Freeman and Ellis' assumption that during the encoding of verbal delayed intentions requiring a motor response, sensorimotor information is generated, thus enhancing memory.

4.2. Study 3: Motor Preparatory Processes in Young and Old Adults

4.2.1. Introduction

Prospective memory has been defined as the cognitive skills that enable us to realize delayed intentions (Ellis & Kvavilashvili, 2000). Delayed intentions are activities that cannot be executed immediately, but have to be postponed until a more appropriate time in the future, and, thus, have to be stored in memory. Ellis (1996) proposed that the representation of a delayed intention in memory should consist of three components: (a) a representation of the intended activity, (b) a representation of the intended execution time, and (c) a representation of the intent itself. The intended activity can be mental (i.e., deciding where to go on holidays), verbal (i.e., passing on a message to another person), or motor (i.e., putting a letter into a post box). The intended execution time can be represented by different characteristics of future occasions for intention execution such as certain times, persons, events, objects, or locations. The representation of the intent refers to the representation of the degree of readiness or commitment to realize the intention in the future.

Experimental paradigms to examine prospective memory performance have mainly used delayed intentions in the form of *verbal instructions* to execute actions at pre-specified times in the future. Since realizing delayed intentions is of fundamental importance for leading an independent and autonomous lifestyle, most experimental studies on prospective memory have focused on its functioning in old age (McDaniel & Einstein, 2007; Kliegel, Mackinley, & Jäger, 2008b). An intriguing finding from this line of research is that although old adults are typically worse than young adults in executing delayed intentions at the intended times (for a meta-analysis see Henry, MacLeod, Philipps, & Crawford, 2004), they retrospectively recall the content of these intentions as well as young adults, even when these are complex and composed of several actions in a specific order (Kliegel, Eschen, & Thöne-Otto, 2004; Kliegel, McDaniel, & Einstein, 2000). This finding is in marked contrast to the age-related decline well documented for free recall of other verbal materials such as word lists or stories (for a review see Craik, 2000).

The age invariance in free recall of delayed intentions typically used in prospective memory paradigms may be caused by the requirement to *enact* the intended actions later, whereas memory tests for other verbal materials usually require only *verbal report* of the encoded information. In young adults, a memory advantage, termed by Freeman and Ellis (2003a) the *intended enactment effect*, has been repeatedly reported for action verbs or phrases that were encoded for later enactment in comparison to action verbs or phrases that were encoded for later verbal report. It has been demonstrated by faster recognition latencies, higher recognition (Freeman & Ellis, 2003a) and free recall accuracy (Engelkamp, 1997; Freeman & Ellis, 2003a; Jahn & Engelkamp, 1997; Koriat, Ben-Zur, & Nussbaum, 1990). Importantly, free recall has been found to be better for action phrases that participants expected to enact regardless of the actual later recall mode, i.e., enactment or verbal report (Koriat, Ben-Zur, & Nussbaum, 1990).

For old adults, Freeman and Ellis (2003b) found a similar intended enactment effect as for young adults, as indicated by a similar reduction of recognition latencies and false alarms and a similar increase of recognition and free recall hits for action verbs encoded for later enactment as compared to action verbs encoded for later verbal report. However, in contrast to the age invariance in free recall of delayed intentions used in prospective memory research, the young adults outperformed the old adults in all these retrieval measures except recognition hits for both types of action verbs. Like Freeman and Ellis (2003b), Norris and West (1993) reported a comparable free recall advantage for old and young adults for semantically unrelated action phrases that were encoded for later enactment as compared to action phrases that were encoded for later written recall. They also found a better free recall for both types of action phrases by the young adults compared to the old adults. However, with action phrases that were organized into four semantic categories (movements with hands, legs, arms, or torso, respectively) a significant intended enactment effect was only observed for the old adults. This lead to the extinction of age differences, whereas the old adults recalled fewer semantically related action phrases than the young adults in the written recall condition. Brooks and Gardiner (1994) also reported a better free recall for young as compared to old adults for semantically unrelated action phrases encoded for both later enactment and later verbal report. In contrast to Freeman and Ellis (2003b) and Norris and West (1993), they did not find a recall advantage for the action phrases that were encoded for later enactment for their old participants, but neither for their young participants. In conclusion, these finding indicate that old adults seem to show at least a similar memory advantage for action verbs and phrases encoded for later enactment as compared to later verbal retrieval. Moreover, this memory advantage can lead to age invariance in free recall for to-be-enacted actions which has been also observed for the verbal instructions to perform actions at a later time that are typically applied as delayed intentions in prospective memory research.

According to Freeman and Ellis (2003a), the memory advantage for action verbs or phrases intended for later enactment as opposed to later verbal report may be caused by the generation of additional sensorimotor information about the intended actions (e.g., their force, direction, duration) in preparation for their later execution during encoding, which later enhances memory. The proposal by Freeman and Ellis is supported by the following findings. In young adults, the intended enactment effect was lost (a) when a secondary motor task, but not when a secondary verbal task, was introduced concurrent to encoding, and (b) when to-be-enacted and to-be-reported actions were enacted during encoding (Freeman & Ellis, 2003a). This indicates an overlap between mental processes during action execution and encoding of actions for future execution, particularly in preparatory motor processes. Freeman and Ellis (2003b) replicated the latter finding with old adults, suggesting that also in old adults the intended enactment effect is related to motor preparatory processes during the encoding of action verbs for later enactment.

Furthermore, in an fMRI study with young adults, our research group (Eschen et al., 2007) could demonstrate that during the encoding of action verbs for later enactment with the right arm in contrast to the encoding of action verbs for later verbal report, a left-lateralized network of brain regions known to be involved in covert motor preparation, i.e., the postcentral gyrus, the precuneus, the dorsal and ventral premotor cortices, the posterior middle temporal gyrus, and the inferior parietal lobule, was differentially activated. We also included an additional condition of encoding of abstract verbs for later verbal report to investigate whether the semantic motor information inherent in action verbs in contrast to abstract verbs activates motor brain regions different from those involved in the encoding of action verbs for later enactment. There was no overlap between the brain regions differentially activated during encoding of action verbs for later enactment in contrast to later verbal report and the brain regions differentially activated during the encoding of action verbs in contrast to abstract verbs for later verbal report. This suggests that during encoding of action verbs for later enactment not only more semantic information about the to-be-enacted verbs is retrieved, but, as Freeman and Ellis (2003a) suggested, motor processes in preparation for later enactment take place.

The present study aims at extending the findings from this fMRI study in two ways. First, since old adults show at least a similar memory advantage for action verbs encoded for later enactment in comparison to action verbs encoded for later verbal report as young adults, we wanted to examine whether this is also based on additional motor preparatory processes during the encoding of action verbs for later enactment and, therefore, on a similar activation of motor brain regions as in young adults. However, neuroimaging studies on encoding of verbal materials in aging (for reviews see Dennis & Cabeza, 2008; Grady, 2008; Park & Gutchess, 2005) have found a differential brain activation pattern for old adults as compared to young adults, even when they perform equally well as young adults on subsequent recognition tests, probably caused by age-related changes in anatomy and physiology of the brain. Specifically, the old adults often show a decreased activation of midtemporal and left prefrontal regions, but an additional activation of right prefrontal regions. Up to now, there are discrepant findings as to whether the additional right prefrontal activation is compensatory or reflects a difficulty in recruiting specific task-relevant or inhibiting task-irrelevant brain regions. Consequently, old adults may show a different pattern of brain activation than young adults during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report.

Second, from our previous fMRI study it is unclear to what extent the brain regions more highly activated during the encoding of action verbs for later enactment as opposed to the encoding of action verbs for later verbal report were related to imagery of the to-be-enacted actions. All participants of the study reported that they had imagined themselves or another person executing the to-be-enacted actions during encoding, whereas they used more semantic or no specific encoding strategies for the to-be-reported actions. In addition, almost all brain regions that were differentially activated during the encoding of the to-be-enacted actions have previously been found to be involved in imagery of actions. Therefore, in order to suppress the differential imagery of the to-be-enacted actions, in the present study the participants were not only presented action verbs during encoding for later enactment or later verbal report, but simultaneously also short videos of a human model pantomiming the respective actions with the right arm. Since abstract verbs are very difficult to pantomime, the condition of encoding of abstract verbs for later verbal report was replaced by a condition in which the participants were asked to watch similar action stimuli as in the other two conditions. This new baseline condition has also the advantage that by contrasting the encoding of action verbs for later verbal report with watching similar action stimuli, it is possible to compare brain regions specifically activated in the encoding of action verbs for verbal report with brain regions previously identified as important for encoding of other verbal stimuli for later verbal report.

4.2.2. Method

4.2.2.1. Participants

Eighteen young (allowed age range: 18 to 30 years) and 17 old (allowed age range: 60 to 75 years) healthy right-handed native German speakers participated in the study. The study was approved by the Specialized Subcommission for Psychiatry, Neurology, and Neurosurgery of the Ethics Commission of the Canton Zurich.

The young adults were recruited through public postings and mailing lists; the old adults were recruited from a volunteer pool of community dwelling elderly adults of the Department of Psychology of the University of Zurich. Young and old adults interested in study participation were sent detailed written information about the study procedure, inclusion criteria, the MRI technique and possible associated risks, a consent form for study participation, a screening questionnaire for MRI safety requirements, a handedness screening questionnaire (the Edinburgh Inventory; Oldfield, 1971), and a health screening questionnaire. They were asked to send the completed consent form and screening questionnaires back to the experimenter if they were willing to participate in the study and fulfilled the inclusion criteria. Any open questions regarding these materials were resolved via phone or email.

According to the screening questionnaires, all included study participants met MRI safety requirements, were right-handed, and did not report any neurological, systemic, or psychiatric disorders or substance use known to affect brain function nor any sensory or motor impairments interfering with study participation. None of the participants took psychoactive medication. However, in accordance with the recommendations of Gazzaley and D'Espositio (2005), we allowed for antihypertensive, antihyperlipidemic, and aspirin medication in the old participants as these are very commonly used by in the elderly population. The young adults received course credit or payment for their study participation. The old adults received payment for their study participation.

None of the participants had cognitive abnormalities as confirmed by a neuropsychological screening examination (see below). One young and two old participants withdrew from MRI scanning because of anxiety. Another old participant was excluded from the study because her T2-weigthed anatomical scan revealed small lacunar infarcts in the white matter of both cortex hemispheres, in the basal ganglia, and in the midbrain. All other participants had no structural abnormalities according to the examination of their T1- and T2-anatomical scans by a neuroradiologist. Finally, a young participant was excluded from the study because he reported to have confused the encoding conditions of the experimental task (see below) during fMRI scanning.

Detailed demographic information for the remaining 16 young and 14 old participants, their scores on the Edinburgh Inventory, and the results of the statistical analyses for differences between the two participant groups on these variables are presented in Table 7. Out of the 14 remaining old participants, 2 took antihypertensive medication, 1 antihyperlipidemic medication, and 1 aspirin cardio. The results of the statistical analyses revealed that the young and the old participants significantly differed in age and years of schooling, whereas both groups had a similar gender distribution and similar handedness scores on the Edinburgh Inventory. The finding of fewer years of schooling for old participants as compared to young participants is typical for similarly aged European volunteer samples (Staudinger & Baumert, 2007).

4.2.2.2. Procedure

The study consisted of two experimental sessions. The first session consisted of a neuropsychological examination. This was mainly done to screen the old participants for cognitive impairments indicative of preclinical (such as Mild Cognitive Impairment, Winblad et al., 2004) or clinical dementia and to compare young and old participants for basic cognitive abilities. For the young participants, this session lasted about 30 min, for the old participants about 50 min. In the second session, the participants completed the experimental task and functional and structural brain imaging took place. This session lasted for both participants about 60 min.

Table 7. ***Comparison of the Young and Old Participants for Demographic Variables and Handedness***

	Young *Mdn (Range)* Minimum -Maximum	Old *Mdn (Range)* Minimum -Maximum	Statistics
Age (in years)	24.5 (11) 19 - 30	64 (15) 60 – 75	$U < 0.001$, $p < .001$
Gender[a]	9 women, 7 men	8 women, 6 men	$\chi^2(1, N = 30) = 0.002$, $p = .961$
Years of schooling[b]	16.06 (2.11) 13 - 20	13.14 (2.53) 10 – 19	$t(28) = 3.439$, $p = .002$
Handedness (Edinburgh Inventory Laterality Index)	100.00 (40.00) 60 - 100	100.00 (20.00) 80 - 100	$U = 109.50$, $p = .918$

Note. Medians, ranges, and *U* are reported because Mann-Whitney tests were used as the variables were not normally distributed. [a]χ^2 test was used because gender is nominal. [b]*M*, *SD*, and *t* are reported because independent *t* test was used as variable was normally distributed.

4.2.2.3. Materials

1) Neuropsychological tests

In the neuropsychological examination, all participants completed neuropsychological tests for the following cognitive domains: crystallized intelligence, speed, memory (short-term memory, working memory, and episodic memory), language (verbal fluency), and executive functioning (task switching). The old participants additionally completed a dementia screening test.

Crystallized intelligence was assessed with the German standard test, i.e., the Mehrfachwahlwortschatztest B (MWT-B; Lehrl, 1977), a multiple-choice vocabulary test. IQ scores are available.

Speed was measured with the Part A of the Trail Making Test (TMT; Reitan, 1955; version and norms according to the new extended German online version of the Consortium to Establish a Registry for Alzheimer's Disease Neuropsychological Assessment Battery, CERAD-Plus online; Memory Clinic Basel). Raw scores are the times (in s) the participants need to connect randomly distributed digits (1 - 25) in ascending order.

Short term memory was assessed with the Digit Span forward subtest of the German version of the Wechsler Memory Scale - Revised (Härting et al., 2000). Possible minimum and maximum raw scores are 0 and 12.

Working memory was tested with the Digit Span backward subtest of the German version of the WMS-R. Possible minimum and maximum raw scores are 0 and 12.

Episodic memory was measured with the Logical Memory I and II subtests of the German version of the WMS-R. In the Logical Memory I subtest, immediate recall of two short stories is tested, in the Logical Memory II subtest delayed recall (20 - 30 min) for these two stories. Possible minimum and maximum raw scores for both subtests are 0 and 50.

Verbal fluency was assessed with the semantic fluency subtest of the Regensburger Wortflüssigkeits-Test (RWT; Aschenbrenner, Tucha, & Lange, 2000). Raw scores are the number of different animals participants are able to name within 1 min.

Task switching was measured with the Part B of the CERAD-Plus online version of the Trail Making Test. Raw scores present the times (in s) the participants need to alternately connect randomly distributed digits (1 - 13) and letters (A - L) in ascending or alphabetical order, respectively.

Dementia screening for the old participants was done with the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). Possible minimum and maximum are 0 and 30.

2) Experimental task

Apart from some modifications, the same task as in our previous fMRI study (Eschen et al., 2007) on encoding of actions for later enactment was employed. As before, in the beginning of the second experimental session, participants were informed with written and oral instructions that the experimental task consisted of three phases. In the *encoding phase*, they were to learn actions for two different types of later recall (i.e., later verbal report or later enactment). In the *recognition phase*, they were to see all learned actions again as well as the same number of new actions and were to decide which actions they had seen before and which not. In the *recall phase*, they were to recall the learned actions by either enacting them or naming them to the experimenter. The encoding and recall phases were demonstrated and exercised with a practice task. Subsequently, fMRI data was acquired while the participants completed the encoding phase. The recognition and recall phases took place outside of the scanner.

The *encoding phase* consisted of three conditions. Two conditions were similar to those employed in our previous study: in the *actions for enactment condition (ENACT)* the participants saw action verbs that they were to encode for later enactment with the right arm and in the *actions for verbal report condition (REPORT)* the participants saw action verbs that they were to encode for later verbal report. However, this time they not only saw action verbs, but simultaneously also a short video of a human model performing these actions with the right arm. The previous *abstract verbs for verbal report condition (ABSTRACT)* was now replaced by a *watch actions condition (WATCH)*, in which the participants were asked to watch similar action videos as in the other two conditions with no further requirement. This condition served as the baseline condition.

All action verbs consisted of one word. The action verbs for the different encoding conditions were matched for length (for detailed data see Table 9 in the Results section). In order to obtain a first-person visual perspective, action enactment was videotaped from above while a female actor pantomimed the actions with her right forearm sitting on a black table. All actions started from the same resting position (bent forearm). The actions were enacted twice before the forearm was moved back into the resting position. The videos were edited with Vegas Movie Studio Platinum Edition 8 (Sony Creative Software, Madison, WI). Subsequently, all videos lasted exactly 4 s and showed the right forearm enacting the action in the lower part of the screen and the respective action verb in the same font and size at the same position in the upper part of the screen. Encoding condition was signalled by the colour of the action verbs: for the ENACT condition action verbs were presented in yellow, for the REPORT condition action verbs were presented in turquoise, and for the WATCH condition action verbs were presented in red.

As in the previous study, for fMRI data acquisition a block-design was adopted. For each condition, 24 videos were shown (each for 4 s with an interstimulus interval depicting a black screen for 2 s) in three blocks of 8 videos. For the ENACT and REPORT conditions, 24 different videos were presented, whereas for the WATCH condition the same 8 videos were presented in a different order in each of the three blocks. The nine blocks were presented to all participants in the following order: REPORT, WATCH, ENACT, REPORT, ENACT, WATCH, ENACT, WATCH, and REPORT. Before the videos were shown, the following short version of the instructions was presented to the participants for 10 s: “Red actions: Just watch!, Turquoise verbs: Learn and report later!, Yellow verbs: Learn and enact later!”. A schematic illustration of the experimental procedure of the encoding phase can be seen in Figure 5.

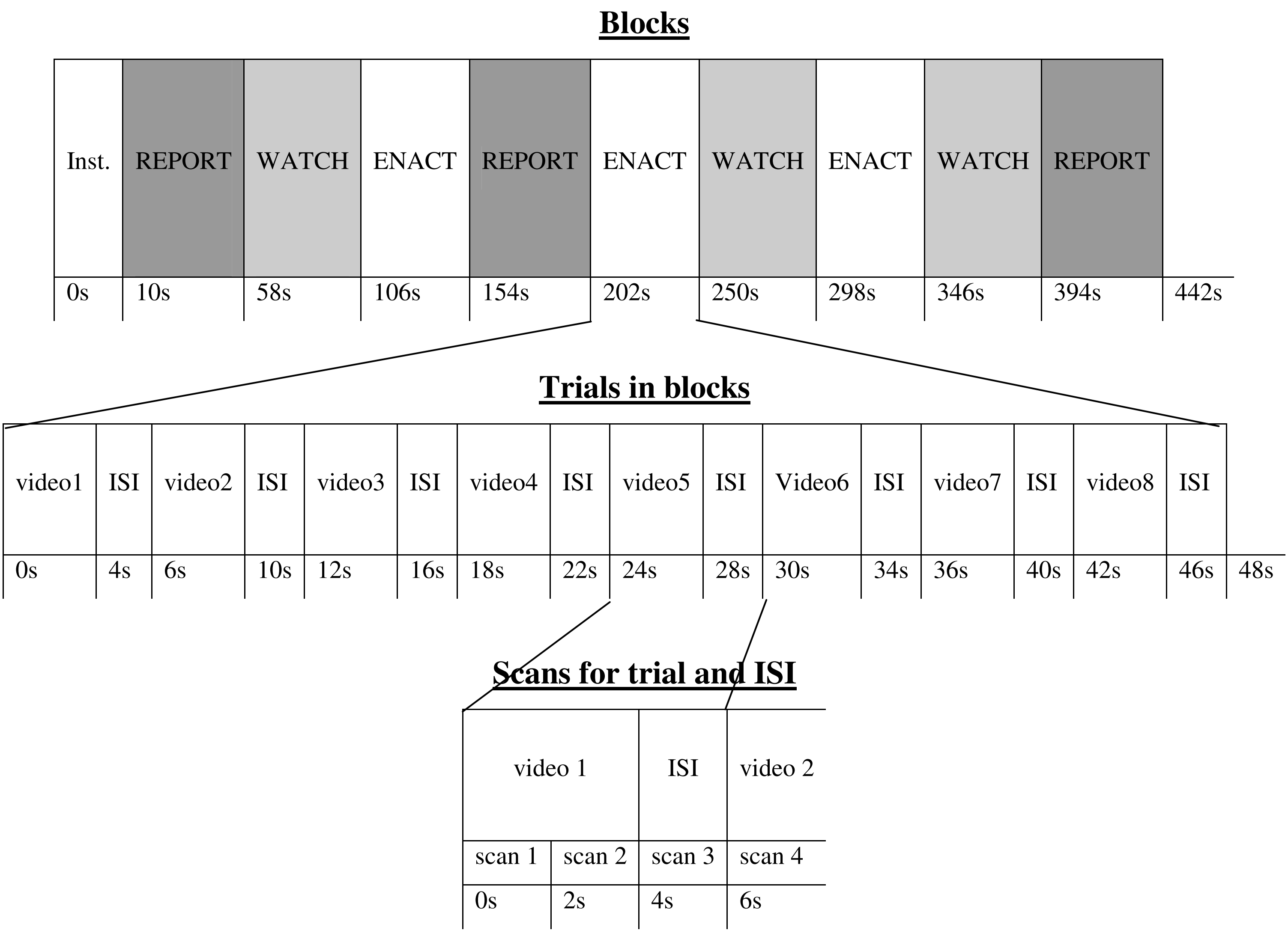

***Figure 5*. Schematic Illustration of the Experimental Procedure of the Encoding Phase.**
Note. Inst. = Instruction.

In the *recognition phase* the participants were shown the 48 action verbs they had encoded in the encoding phase mixed with 48 new similar action verbs that served as distracter items on a computer laptop. The participants had to indicate by key press whether they had already learned a word in the encoding phase or not (*B* key for encoded verbs, *N* key for new verbs). The action verbs were presented in white colour at fixation on a black screen for self-paced durations with an interstimulus interval of 2 s (showing a white fixation cross on a black screen).

In the *recall phase* participants were asked to enact those actions with the right arm and to verbally report those actions that they had encoded for the respective recall mode.

3) Action verb ratings

In the second experimental session, subsequent to the completion of the experimental tasks, the participants were asked to rate the 56 action verbs that were presented to them in the encoding phase of the experimental task for familiarity, imaginabilty, concreteness, and executabilty with one arm. Since for most of the 56 action verbs no German normative data for these variables was available, this was done to check retrospectively that the actions presented in the different encoding phase conditions did not vary in these variables. Ratings were collected with seven-point rating scales (from 1 to 7) with the anchor point 1 defined as *very unfamiliar, verb does not or very difficultly and very slowly provoke an image, very abstract,* or *not executable with one arm,* respectively, and the anchor point 7 defined as *very familiar, verb provokes very easily and very quickly an image, very concrete,* or *very well to execute with one arm,* respectively.

4.2.2.4. Apparatus

The fMRI and MRI measurements were carried out on a 3 T scanner (Signa EXCITE, General Electrics, Milwaulkee, WI) using a standard head coil. The participants wore ear plugs to reduce scanner noise as well as headphones and video goggles of the VisuaStim Digital system (Resonance Technology, Northridge, CA). The stimuli for the encoding phase were presented with a PC via Presentation® software (Neurobehavioral Systems, Albany, CA) and projected to the video goggles. For the recognition phase, stimuli were presented and participants' responses were collected using Presentation® software.

4.2.2.5. Image acquisition protocol

Functional magnetic resonance image acquisition during the encoding phase of the experimental task was performed using a T2-weighted gradient echo, echoplanar imaging sequence sensitive to blood oxygen level dependent (BOLD) contrast (repetition time (TR) = 2000 ms; echo time (TE) = 32 ms; flip angle = 50°; matrix size = 128 x 128; field of view (FOV) = 256 x 256 mm^2). Altogether 250 scans were acquired. Each scan consisted of 26 slices acquired at contiguous locations approximately parallel to the anterior-posterior commissure line without intersclice gap in an interleaved order with a slice thickness of 3.8 mm and a 1.9 x 1.9 mm^2 in-plane resolution. Before functional imaging, additionally a T2-weighted anatomical scan of the brain was acquired (TR = 7500 ms; TE = 97.6 ms; flip angle = 90°; matrix size: 256 x 256; FOV = 256 x 256 mm^2). This anatomical scan consisted of 26 slices co-planar with the slices of the functional images. The 26 slices were acquired without interslice gap in sequential order with a slice thickness = 3.8 mm and 0.94 x 0.94 mm^2 in-plane resolution. Whole acquisition time for this anatomical scan was approximately 2.5 min. Furthermore, after the functional imaging, a high-resolution T1-weighted anatomical scan of the brain were obtained (TR = 9.4 ms; TE = 2.1 ms; flip angle = 20°; matrix size: 256 x 256; FOV = 256 x 256 mm^2). This anatomical scan consisted of 172 three-dimensional spiral slices acquired in sequential order with a slice thickness of 1 mm and a 0.94 x 0.94 mm^2 in-plane resolution. Whole acquisition time for the second anatomical scan was approximately 6.5 min.

4.2.2.6. FMRI data analysis

The fMRI data were analysed using Statistical Parametric Mapping (SPM5, Wellcome Department of Cognitive Neurology, London, UK). The first 5 scans (acquired during instruction presentation) were discarded to allow for steady-state magnetization as well as the last 29 scans (acquired after completion of the encoding phase of the experimental task). The remaining images were realigned and normalized to the standard brain Montreal Neurological Institute (MNI) space (EPI-template), using a voxel size of 2 x 2 x 2 mm^3 and were warped in Y-space. Each normalized scan was smoothed with a 6 mm full-width at half maximum isotropic Gaussian kernel.

For each participant, the functional data to all stimuli of the encoding phase were entered into a single design matrix, in which the start and end time of each block of the two encoding conditions (ENACT and REPORT) were specified in scan number. The WATCH condition served as baseline. Then the general linear model (settings: high pass filter: 128, low pass filter: hrf, no global scaling, no corrections for serial correlations) was applied. Two *t* contrast images of interest were computed for each subject: ENACT-REPORT (by defining the ENACT condition as a predictor that assumed the value of 1 for its respective volumes and defining the REPORT condition as a predictor that assumed the value of -1 for its respective volumes) and REPORT versus WATCH (by defining REPORT as a predictor that assumed the value of 1 for its respective volumes and 0 for the other volumes).

Subsequently, these single-subject first-level contrasts were entered into second-level random-effect analyses to allow for population inference. The whole sample averages for the two contrasts of interest were calculated with one-sample *t* tests and group differences with two-sample *t* tests. For the sample averages a threshold of $P < 0.001$ (uncorrected) was used, for the group differences a threshold of $P < 0.005$ (uncorrected) was applied. Subsequently, a cluster size correction with the minimum number of voxels thresholded at $P < 0.05$ was applied: for the whole sample averages of the two contrasts of interest this corresponded to 27 voxels, for the group differences to 52 voxels for the ENACT-REPORT contrast and to 49 voxels for the REPORT vs. WATCH contrast. The MNI coordinates of activated clusters were transformed into the Talairach coordinates with the MNI2TAL tool written by Matthew Brett. The activated brain areas were identified using the Talairach Daemon (University of Texas, Austin, TX).

4.2.3. Results

4.2.3.1. Neuropsychological tests

All participants showed normal test performance (greater than one standard deviation below age-adjusted norms) on all applied neuropsychological tests, except the short term memory test and the verbal fluency test. On the short term memory test (Digit Span forward) five old participants showed just under-average performance (5/12 points: for four participants aged between 60-64 years z = -1.44; for one participant aged 65 years z = -1.11). One of these participants (aged 64 years) also showed just under-average performance in the verbal fluency test (semantic fluency subtest of the Regensburger Wortflüssigkeits-Test, RWT: 14 animals: PR = 12). However, these test performances were judged as being still within the normal variance and not indicative for preclinical or clinical dementia (for which mainly a cut-off of 1.5 standard deviation below age-adjusted norms is employed, Loewenstein et al., 2006). Furthermore, as can be seen in Table 14, the scores of the old participants on the dementia screening instrument (MMSE) were in the normal range (greater than 27). Moreover, the old participants performed within the normal age range for the two measures of episodic memory (Logical Memory I and II). Episodic memory impairments have been established as the earliest marker of the most common type of dementia, i.e., Alzheimer's Disease (see Bäckman, Small, & Fratiglioni, 2004 for a review).

Table 8 presents the raw scores on the applied neuropsychological tests separately for the young and the old participants as well as the results of independent t tests for the group comparisons for these data. The old participants showed typical age-related deficits and preservations in the tested cognitive abilities (Park, 2000; Schaie, 2005). They performed worse than the young participants adults in the speed, working memory, immediate (although this difference between the young and old participants was just marginally significant) and delayed free recall, and task switching tests, whereas they performed equally well in the crystallized intelligence and verbal fluency tests. Only the finding of their worse performance in the short term memory test is unusual with regard to the cognitive aging literature (Craik, 2000).

Table 8. ***Comparison of the Young and Old Participants for Neuropsychological Test Results***

	Young *M* (*SD*) Minimum - Maximum	Old *M* (*SD*) Minimum - Maximum	Independent *t* test *t* (28)
Crystallized intelligence (IQ)	111.75 (10.08) 100 - 136	116.21 (14.69) 93 – 136	-0.98
Speed (TMT-A, in s)	19.44 (4.26) 15 -28	34.07 (7.88) 20 – 50	-6.44***
Short term memory (Digit Span forward)	8.63 (1.86) 6 – 12	6.50 (1.40) 5 – 9	3.50**
Working memory (Digit Span backward)	8.31 (1.54) 6 – 12	6.21 (0.89) 5 – 8	4.48***
Immediate recall (Logical Memory I)	34.69 (5.46) 27 – 45	30.57 (5.64) 21 – 37	2.03†
Delayed recall (Logical Memory II)	32.06 (5.87) 26 – 43	27.29 (5.09) 17 – 35	2.54*
Verbal fluency (RWT)	26.00 (3.97) 19 – 33	23.86 (5.97) 14 – 36	1.17
Task switching (TMT-B, in s)	45.44 (12.94) 26 – 67	83.79 (26.00) 57 – 150	-5.22***
MMSE[a]		29.29 (0.61) 28 – 30	

Note. [a]MMSE was only completed by the old participants. †$p = .052$. *$p < .05$. **$p < .01$. ***$p < .001$.

4.2.3.2. Characteristics of the action verbs employed in the three encoding phase conditions of the experimental task

Since for the interpretation of differences in the behavioural performance and brain activation during the three encoding phase conditions of the experimental task, the matching of the presented action stimuli is of critical importance and for most employed action verbs appropriate normative data was not available, the participants were asked to rate the 56 action verbs used in the encoding phase of the experimental task for familiarity, imaginability, concreteness, and executability with one arm on seven-point rating scales. Higher rating scores indicate higher familiarity, imaginabilty, concreteness, or executability with one arm, respectively. Table 9 provides the mean ratings of all participants on these variables for the 24 action verbs used in the ENACT, for the 24 action verbs used in the REPORT, and the 8 action verbs used in the WATCH condition as well as the results of the statistical analyses for differences in these ratings between the three conditions. In addition, mean number of letters and syllables of the action verbs used in the three encoding phase conditions and the results of the statistical analyses for condition differences in these variables are presented. As can be seen in Table 9, the participants regarded the action verbs employed in the three encoding phase conditions of the experimental task as highly familiar, easily and quickly to imagine, highly concrete, and very well to execute with one arm (average rating scores about 6). More importantly, the action stimuli used in the three encoding phase conditions of the experimental task were matched for number of letters and syllables, familiarity, imaginability, concreteness, and executability with one arm.

Table 9. ***Characteristics of Action Verbs Employed in the Three Encoding Phase Conditions of the Experimental Task***

	ENACT $n = 24$ *M* (*SD*)	REPORT $n = 24$ *M* (*SD*)	WATCH $n = 8$ *M* (*SD*)	ANOVA $F\ (2, 53)$
Letters[a]	7.00 (9)	7.00 (7)	7.00 (8)	0.61, $p = .736$
Syllables[a]	2.00 (3)	2.00 (1)	2.00 (2)	0.86, $p = .650$
Familiarity[a]	6.65 (1.37)	6.63 (1.50)	6.73 (0.96)	0.77, $p = .679$
Imaginability	6.06 (0.56)	6.19 (0.60)	5.92 (0.48)	0.72, $p = .491$
Concreteness	6.02 (0.53)	6.15 (0.53)	6.06 (0.33)	0.44, $p = .648$
Executability with one arm	5.72 (0.68)	5.79 (0.61)	5.49 (0.86)	0.60, $p = .551$

Note. [a]Medians, ranges, and χ^2 (2, $N = 56$) are reported because the *H* test was used as variable was not normally distributed.

4.2.3.3. Recognition and recall performance for actions verbs of the ENACT and REPORT encoding phase conditions of the experimental task

To assess if consistent with the action superiority account action verbs encoded for later enactment were more accessible in memory than action verbs encoded for later verbal report and if differences for this greater accessibility in memory existed between the young and old participants, 2x2-mixed ANOVAs with encoding condition (i.e., ENACT versus REPORT) as within-subjects factor and participant group (i.e., young versus old adults) as between-subjects factor on recognition latency, recognition hits percentage, and recall hits percentage were conducted.

Following Freeman and Ellis (2003a, b), for recognition latencies responses with reaction latencies greater than 2 standard deviations from a person's mean latency were removed. This led to the removal of an average of 3.75% of responses to verbs from the ENACT condition and of an average of 4.44% of responses to verbs of the REPORT condition. There were no group differences in the amount of excluded responses in each of the two conditions (ENACT: $U = 110.00$, $p = .951$; REPORT: $U = 100.00$, $p = .637$) and no difference between the two conditions in the amount of excluded responses for the whole sample ($Z = -0.683$, $p = .495$) and in each participant group (young participants: $Z = -0.263$, $p = .793$; old participants: $Z = -0.765$, $p = .444$).

Means and standard deviations for recognitions latencies, recognition hits percentages, and recall hits percentages of all participants, of the young participants, and of the old participants, separately for the ENACT and REPORT conditions as well as for both condition together, are presented in Table 10.

For *recognition latency*, the main effect of encoding condition was significant, $F(1, 28) = 8.62$; $p = .007$. As can be seen in Table 10, in accordance with the action superiority account the mean recognition latencies of the whole sample for the action verbs of the ENACT condition were shorter than those for the action verbs of the REPORT condition. The main effect of group was also significant ($F(1, 28) = 3.67$; $p < .001$), with shorter recognition latencies for the young in comparison to the old participants in both conditions (see Table 10). However, the interaction between encoding condition and participant group was not significant ($F(1, 28) = 1.26$; $p = .272$), indicating that the recognition latency advantage for action verbs encoded for later enactment as compared to actions verbs encoded for later verbal report was of equal size in the young and the old participants. As can be seen in Table 10, both young and old participants recognized the action verbs encoded for later enactment faster than the action verbs encoded for later verbal report.

Table 10. ***Recognition and Recall Performance of the Whole Sample, the Young, and the Old Participants for All Actions Verbs and for Actions Verbs of the ENACT and REPORT Conditions***

	Group	ENACT *M* (*SD*)	REPORT *M* (*SD*)	Both Conditions *M* (*SD*)
Recognition latency (in ms)	All	1377.00 (304.58)	1477.62 (383.58)	1434.78 (58.48)
	Young	1254.91 (221.70)	1390.51 (271.94)	1322.71 (79.89)
	Old	1516.53 (333.06)	1577.17 (472.10)	1546.85 (85.41)
Recognition hits (in %)	All	82.22 (9.96)	72.78 (12.70)	77.27 (1.76)
	Young	86.20 (8.83)	75.26 (12.77)	80.73 (2.40)
	Old	77.68 (9.47)	69.94 (12.47)	73.81 (2.57)
Recall hits (in %)	All	23.33 (11.03)	15.69 (10.13)	19.18 (1.26)
	Young	28.91 (8.67)	19.53 (11.76)	24.22 (1.72)
	Old	16.96 (10.14)	11.30 (5.52)	14.14 (1.84)

For *recognition hits percentage*, again the main effect of encoding condition was significant, $F(1, 28) = 22.17$; $p < .001$. As can be seen in Table 10, in accordance with the action superiority account the mean recognition hits percentage of the whole sample for the action verbs of the ENACT condition was higher than that for the action verbs of the REPORT condition. The young participants correctly recognized a higher percentage of action verbs encoded in both conditions than the old participants (see Table 10), however, the main effect of group just failed to reach significance, $F(1, 28) = 3.67$; $p = .059$. Again, the interaction between encoding condition and participant group was not significant, ($F(1, 28) = 0.65$; $p = .427$), indicating that the recognition accuracy advantage for action verbs encoded for later enactment in comparison to action verbs encoded for later verbal report was of equal size in the young and in the old participants. As can be seen in Table 10, both young and old participants correctly recognized a higher percentage of action verbs encoded for later enactment than action verbs encoded for later verbal report.

Furthermore, for *recall hits percentage*, the main effect of encoding condition was significant, $F(1, 28) = 10.30$; $p = .003$. As can be seen in Table 10, in agreement with the action superiority account the mean recall hits percentage of the whole sample for the action verbs of the ENACT condition was higher than that for the action verbs of the REPORT condition. The main effect of group was also significant, $F(1, 28) = 16.10$; $p < .001$. The young participants correctly recalled a higher percentage of actions encoded in both conditions than the old participants (see Table 10). Once more, the interaction between encoding condition and participant group was not significant (*F*(1, 28) = 0.63; *p* = .434), indicating that the recall advantage for action verbs encoded for later enactment in comparison to actions encoded for later verbal report was of equal size in the young and the old participants. As can be seen in Table 10, both young and old participants correctly recalled a higher percentage of action verbs encoded for later enactment than of action verbs encoded for later verbal report.

In summary, consistent with the action superiority account, all retrieval measures clearly demonstrated a memory advantage for action verbs encoded for later enactment as compared to actions encoded for later verbal report. Moreover, for all retrieval measures, the memory advantage for the actions encoded for later enactment was of similar size in the young and in the old participants.

4.2.3.4. Brain regions differentially activated during the ENACT and REPORT encoding phase conditions of the experimental task common to the young and the old participants

Brain regions more highly activated in all participants during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report (ENACT-REPORT) can be seen in Table 11 and Figure 6. These included three left frontal regions, i.e., a region in the left posterior inferior frontal gyrus (BA 9/44) bordering to the left insula (BA 13), a region around the junction of the left precentral and superior frontal sulcus (BA 6/24), and a region in the more anterior and medial BA 6 corresponding according to a meta-analysis on motor brain regions by Grèzes and Decety (2001) and a review on premotor areas by Picard and Strick (2001) to the ventral opercular premotor cortex, the dorsal premotor cortex, and the pre-supplementary motor area; two left parietal regions, i.e., a region with its main centre in the inferior parietal lobule (BA 40) stretching to the precuneus (BA 7) and postcentral gyrus (BA 2) and a more superior region in the postcentral gyrus (BA 5); two right midtemporal regions (see second picture in Figure 6), i.e., one located in the posterior part of the parahippocampal gyrus (BA 19) and one located in the anterior part of the parahippocampal gyrus (BA36) at the junction to the hippocampus; and three occipital regions, i.e., a widespread region in the left lateral occipital lobe reaching to the occipito-temporal junction (BA 18/19) and two approximately corresponding, but smaller and separate, regions in the right lateral occipital lobe (BA17/18) and at the occipito-temporal junction (BA 19), respectively.

Table 11. ***More Highly Activated Brain Regions During Encoding of Actions for Later Enactment as Compared to Encoding of Actions for Later Verbal Report (ENACT-REPORT) in Both Young and Old Participants***

Hemisphere	Anatomical region	BA	Talairach coordinates			*T*	k_E
			x	y	z		
L	Inferior parietal lobule	40	-36	-36	37	7.43	723
	Precuneus	7	-27	-44	41	5.07	
	Postcentral gyrus	2	-40	-29	33	4.61	
L	Inferior frontal gyrus	9	-47	6	28	5.87	218
	Inferior frontal gyrus	44	-45	1	17	4.61	
	Insula	13	-40	-7	15	3.80	
L	Fusiform gyrus	19	-40	-65	-9	5.40	1220
	Inferior occipital gyrus	18	-30	-83	-3	5.33	
	Middle occipital gyrus	18	-34	-85	2	5.24	
R	Lingual gyrus	18	20	-98	-4	5.12	186
	Inferior occipital gyrus	17	17	-91	-7	5.12	
	Middle occipital gyrus	18	22	-95	5	4.82	
L	Precentral gyrus	6	-29	-11	52	4.71	178
	Anterior cingulate	24	-18	-15	46	4.36	
	Middle frontal gyrus	6	-34	-3	52	4.27	
L	Postcentral gyrus	5	-36	-44	56	4.68	28
R	Parahippocampal gyrus	19	29	-44	-1	4.36	39
R	Fusiform gyrus	19	40	-71	-13	4.33	31
L	Medial frontal gyrus	6	-15	10	51	4.26	59
	Superior frontal gyrus	6	-13	8	60	4.09	
R	Parahippocampal gyrus	36	31	-29	-16	4.12	27
	Hippocampus		27	-32	-5	4.01	

Note. L = Left hemisphere. R = Right hemisphere. BA = Brodmann Area. *T* = *T* value of significant activated voxels. k_E = Cluster size.

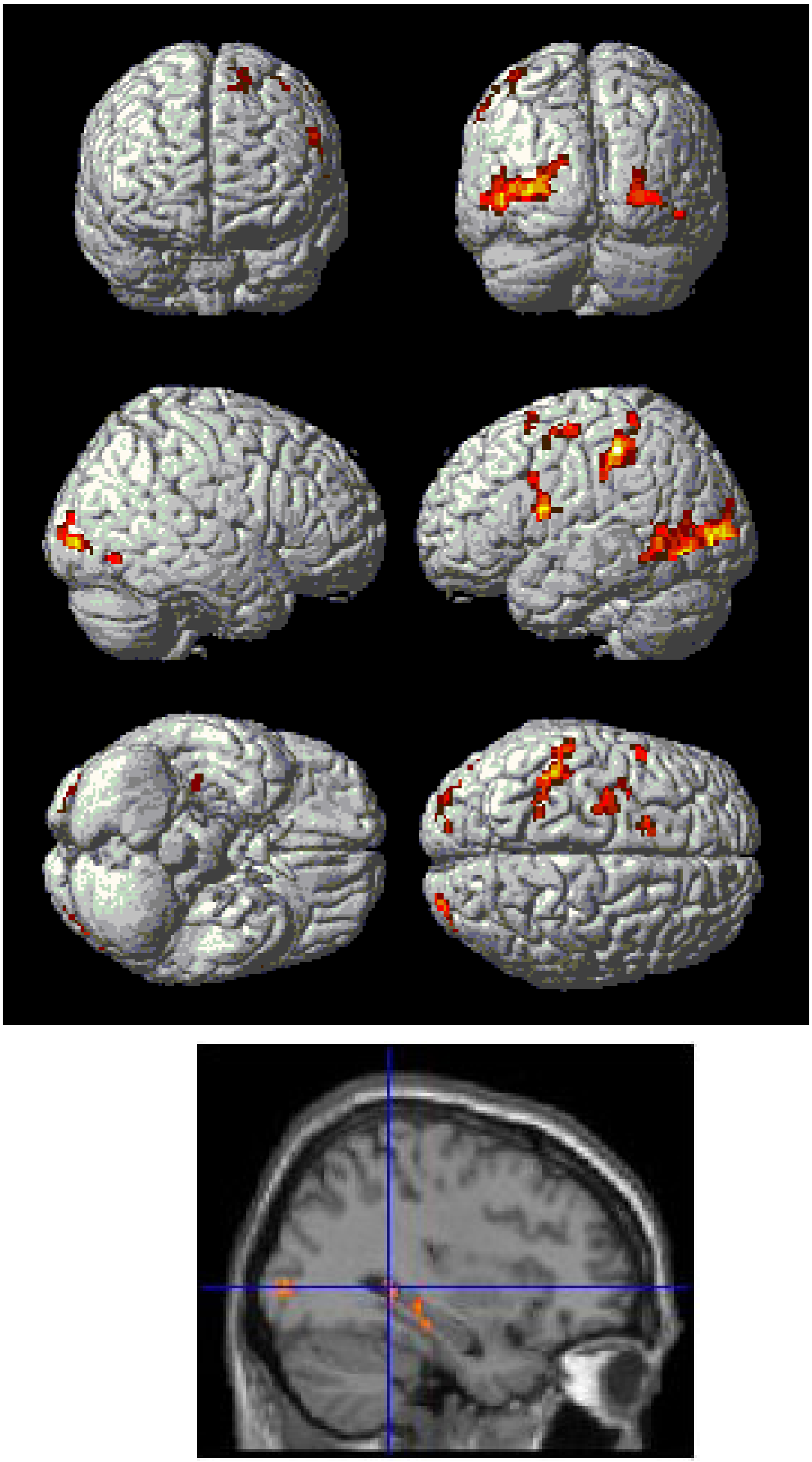

Figure 6. **More Highly Activated Brain Regions During the Encoding of Actions for Later Enactment in Comparison to the Encoding of Actions for Later Verbal Report (ENACT-REPORT) in Both Young and Old Participants.**

Note. First Picture: 1st row: Front and back view. 2nd row: Right and left view. 3rd row: Bottom and top view. Second Picture: Sagittal Slice at x = 29.

Brain regions differentially activated in all participants during the encoding of action verbs and videos for later verbal report in comparison to watching similar action stimuli (REPORT vs. WATCH) can be seen in Table 12 and Figure 7. Only three regions were differentially activated: a region in the right superior temporal gyrus (BA 38), a region (BA13/14) in the left insula stretching to the precentral gyrus at its border to the posterior inferior frontal gyrus corresponding according to the meta-analysis on motor brain regions by Grèzes and Decety (2001) to the ventral opercular premotor cortex, and a region in the left inferior parietal lobule (BA 40).

Table 12. ***Differentially Activated Brain Regions During the Encoding of Actions for Later Verbal Report in Comparison to Watching Similar Action Stimuli (REPORT vs. WATCH) in Both Young and Old Participants***

Hemisphere	**Anatomical region**	**BA**	**Talairach coordinates**			***T***	**k_E**
			x	**y**	**z**		
R	Superior temporal gyrus	38	43	8	-17	6.08	50
L	Insula	13	-44	8	16	5.16	52
	Precentral gyrus	44	-52	10	11	4.26	
L	Inferior parietal lobule	40	-43	-32	35	4.56	40

Note. L = Left hemisphere. R = Right hemisphere. BA = Brodmann Area. *T* = *T* value of significant activated voxels. k_E = Cluster size.

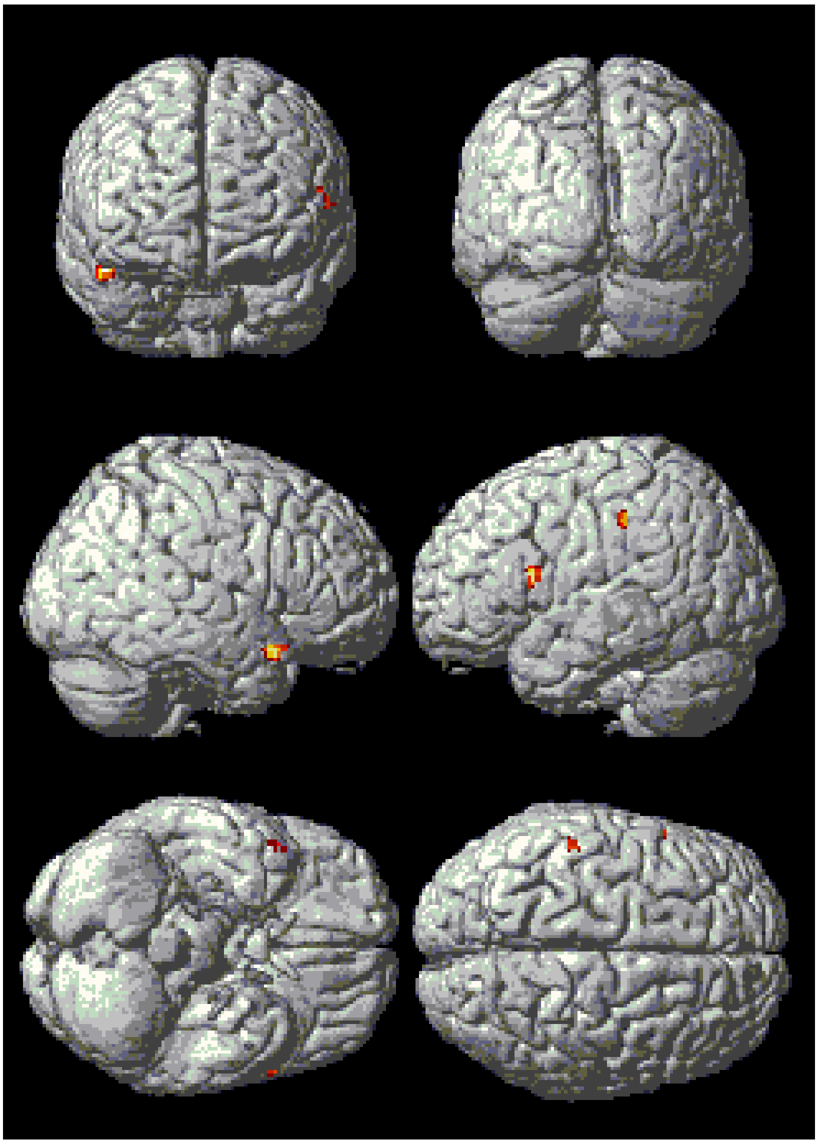

***Figure 7*. Differentially Activated Brain Regions During the Encoding of Actions for Later Verbal Report in Comparison to Watching Similar Action Stimuli (REPORT vs. WATCH) in Both Young and Old Participants.**

Note. 1st row: Front and back view. 2nd row: Right and left view. 3rd row: Bottom and top view.

4.2.3.5. Age differences in brain regions differentially activated during the ENACT and REPORT encoding phase conditions of the experimental task

Brain regions more highly activated by the old than by the young participants during the encoding of action verbs and videos for later enactment in comparison to the encoding of action verbs and videos for later verbal report (ENACT-REPORT) can be seen in Table 13 and Figure 8. These were located in the right dorsomedial prefrontal cortex (BA 8) and in the right inferior parietal lobule (BA 40/39).

The brain region more highly activated by the young than by the old participants during the encoding of action verbs and videos for later enactment in comparison to the encoding of action verbs and videos for later verbal report (ENACT-REPORT) is also presented in Table 13 and, additionally, in Figure 9. It was located at the border of the right caudate body and thalamus.

Table 13. ***Age Differences in More Highly Activated Brain Regions During the Encoding of Actions for Later Enactment as Compared to Encoding of Actions for Later Verbal Report (ENACT-REPORT)***

More Highly Activated Areas for Old Participants							
Hemisphere	**Anatomical region**	**BA**	**Talairach coordinates**			***T***	**k_E**
			x	**y**	**z**		
R	Superior frontal gyrus	8	17	35	42	3.76	61
R	Inferior parietal lobule	40	36	-50	41	3.94	240
	Inferior parietal lobule	40	45	-58	39	3.88	
	Angular gyrus	39	40	-58	39	3.62	
More Highly Activated Areas for Young Participants							
Hemisphere	**Anatomical region**	**BA**	**Talairach coordinates**			***T***	**k_E**
			x	**y**	**z**		
R	Caudate body		15	1	21	4.34	64
	Thalamus		6	-7	19	2.82	

Note. L = Left hemisphere. R = Right hemisphere. BA = Brodmann Area. *T* = *T* value of significant activated voxels. k_E = Cluster size.

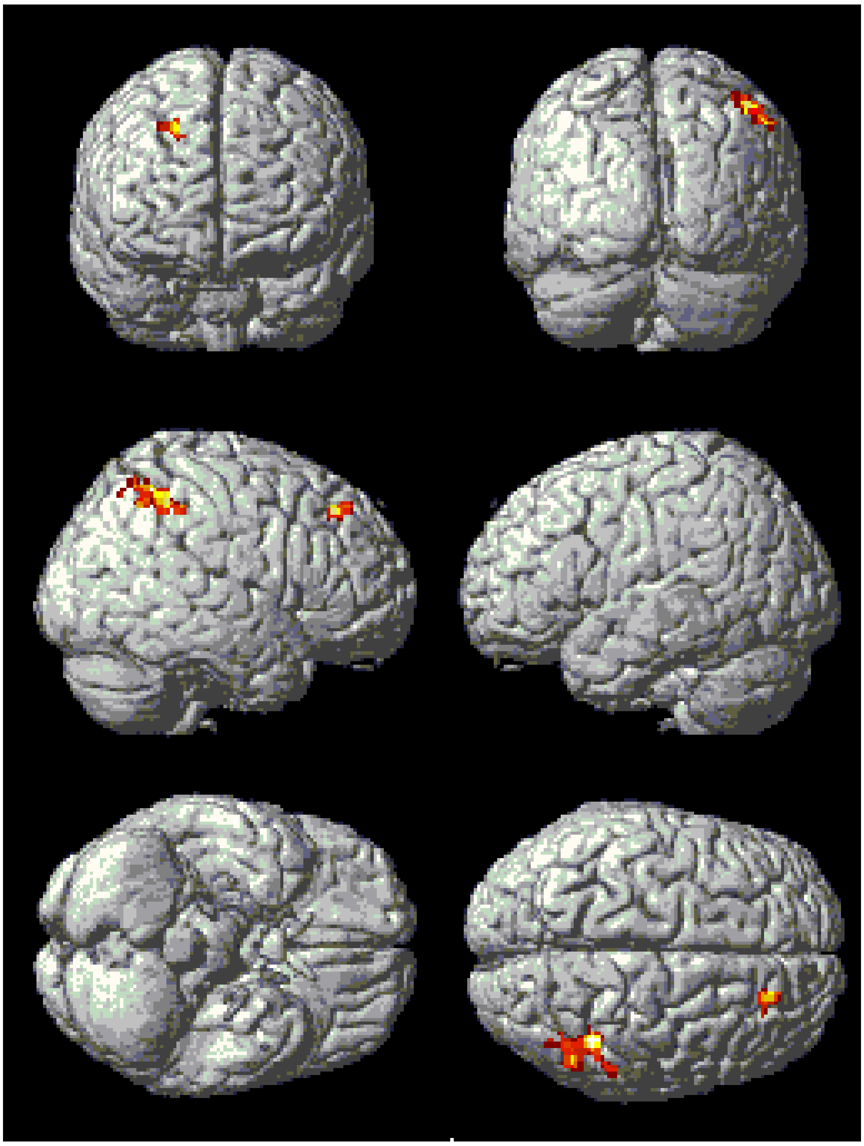

***Figure 8*. Brain Regions More Highly Activated by the Old than by the Young Participants During the Encoding of Actions for Later Enactment in Comparison to the Encoding of Actions for Later Verbal Report (ENACT-REPORT).**

Note. 1st row: Front and back view. 2nd row: Right and left view. 3rd row: Bottom and top view.

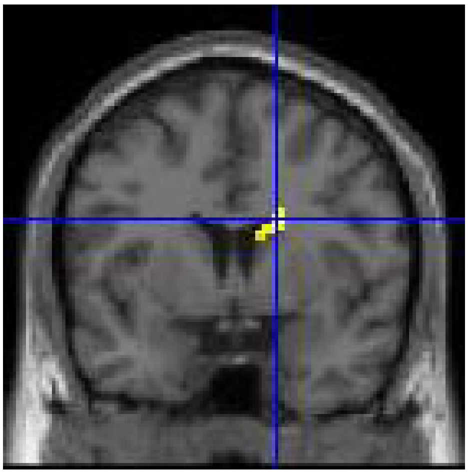

***Figure 9*. Brain Regions More Highly Activated by the Young than by the Old Participants During the Encoding of Actions for Later Enactment in Comparison to the Encoding of Actions for Later Verbal Report (ENACT-REPORT)**.
Note. Coronal Slice at y = 1.

Brain regions more highly activated by the old than by the young participants during the encoding of action verbs and videos for later verbal report in comparison to watching similar action stimuli (REPORT vs. WATCH) can be seen in Table 14 and Figure 10. These included a region in the left posterior cingulate extending to the retrosplenial cortex (BA 31/30/29) and a corresponding, but smaller, region only in the right posterior cingulate (BA 31) (see second picture of Figure 10), a region in the left posterior parahippocampal gyrus (BA 19) and a corresponding, but again smaller, region in the right posterior parahippocampal gyrus (BA 19) (see third picture of Figure 10), a region at the left occipito-temporal junction in the fusiform gyrus (BA 20), a region in the right superior (BA 19) and a region in the right posterior cuneus (BA 17). The young participants did not activate any brain regions more highly than the old participants.

Table 14. ***Brain Regions More Highly Activated by the Old Than by the Young Participants During the Encoding of Actions for Later Verbal Report in Comparison to Watching Similar Action Stimuli (REPORT vs. WATCH)***

Hemisphere	Anatomical region	BA	Talairach coordinates			*T*	k_E
			x	y	z		
R	Posterior cingulate	31	27	-58	16	4.88	326
	Lingual gyrus	19	32	-69	7	4.82	
	Parahippocampal gyrus	19	29	-54	-1	4.29	
L	Posterior cingulate	30	-15	-63	11	4.83	132
	Posterior cingulate	31	-22	-62	14	3.89	
	Cuneus	17	-17	-71	14	3.51	
L	Fusiform gyrus	20	-40	-38	-13	4.79	302
	Fusiform gyrus	20	-40	-29	-14	4.41	
	Parahippocampal gyrus	19	-41	-48	-6	4.20	
R	Cuneus	19	29	-85	24	3.79	55
	Middle temporal gyrus	19	38	-81	24	3.72	
	Cuneus	19	31	-83	31	3.60	
L	Posterior cingulate	29	-17	-46	10	3.44	51
	Lateral ventricle		-22	-38	12	3.20	
L	Parahippocampal gyrus	19	-24	-52	1	3.80	65
	Lingual gyrus	19	-31	-56	0	3.73	
	Parahippocampal gyrus	19	-34	-48	-1	3.22	
R	Cuneus	17	15	-93	7	3.52	49

Note. L = Left hemisphere. R = Right hemisphere. BA = Brodmann Area. *T* = *T* value of significant activated voxels. k_E = Cluster size.

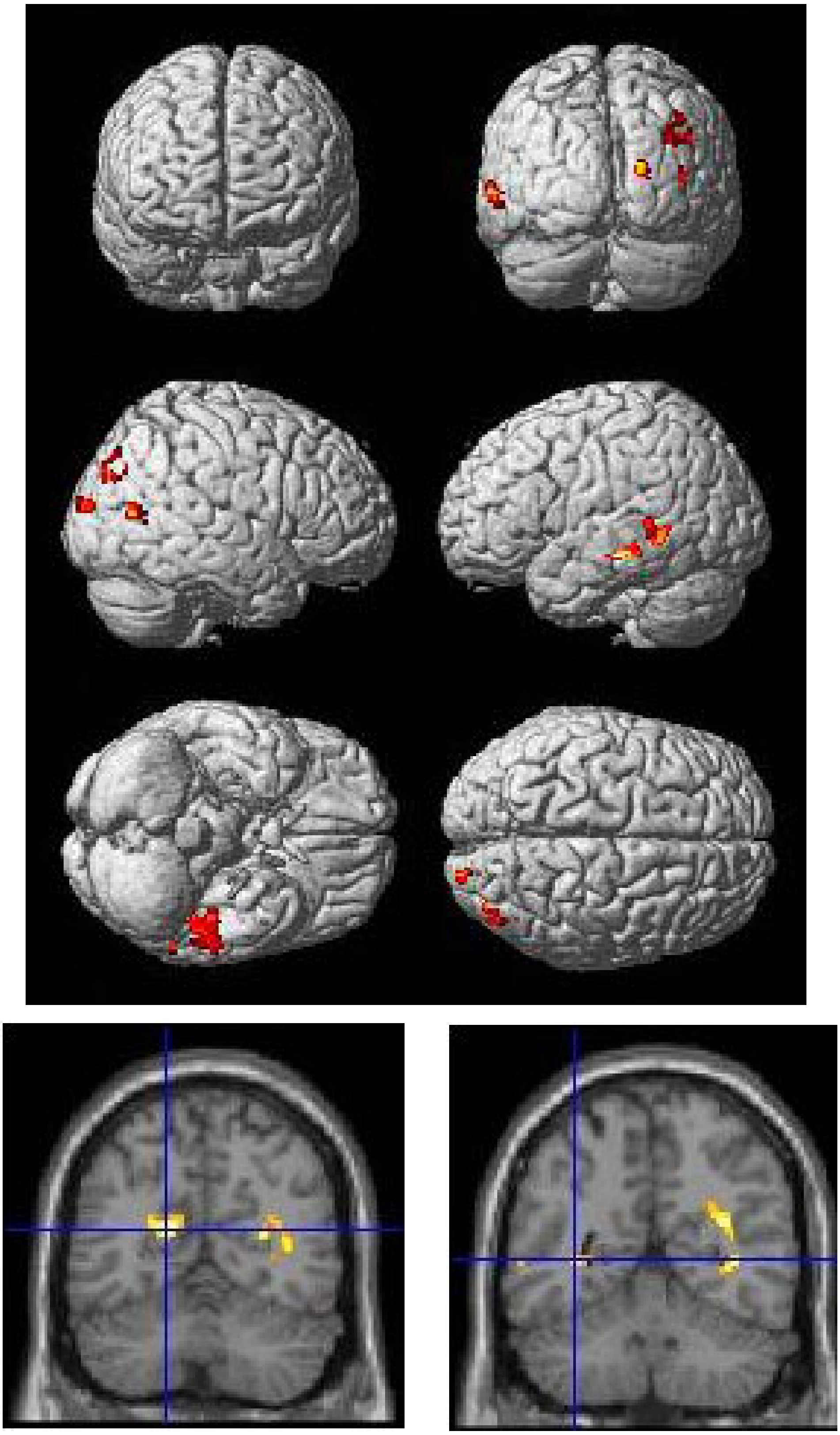

***Figure 10*. More Highly Activated Brain Regions by the Old than by the Young Participants During the Encoding of Actions for Later Verbal Report in Comparison to Watching Similar Action Stimuli (REPORT vs. WATCH).**

Note. First Picture: 1st row: Front and back view, 2nd row: Right and left view, 3rd row: Bottom and top view. Second Picture: Coronal slice at y = -62. Third Picture: Coronal slice at y = -56.

4.2.4. Discussion

In a previous fMRI study with young adults, we have demonstrated that during the encoding of action verbs for later enactment as opposed to later verbal report, brain regions known to be involved in motor preparation were differentially activated, indicating that the memory advantage observed for these action verbs is caused by the additional generation of sensorimotor information in preparation for action execution. Old adults profit at least to a similar degree as young adults from encoding of action verbs or phrases for later enactment as compared to later verbal report. This may cause the age-invariance in free recall of delayed intentions typically used in prospective memory research that have the form of verbal instructions to enact certain actions at certain times in the future.

The aim of the present study was to investigate whether the memory advantage for to-be-enacted action verbs as compared to to-be-reported action verbs in old adults is based on the activation of similar motor brain regions as in young adults or whether, due to age-related changes in brain anatomy and physiology, age-differences in brain activation exist.

In our previous fMRI study, our participants had reported to have imagined themselves or another person to enact the actions they had to encode for later enactment, whereas for to-be-reported action verbs they more often used semantic or no specific encoding strategies. The brain regions that were more highly activated during the encoding of action verbs for later enactment as opposed to the encoding of action verbs for later verbal report have previously found to be involved in imagery of actions. In order to suppress this differential imagery of to-be-enacted actions, in the present study the participants were not only presented action verbs during encoding, but simultaneously videos of a human model pantomiming the respective actions. Because of this modification, the previous baseline condition of encoding of abstract verbs for later verbal report was replaced with a new baseline condition of watching similar action stimuli as those presented for encoding for later enactment and verbal report.

4.2.4.1. Behavioural findings

With this modified paradigm, for both our young and old participants, we observed a memory advantage for action verbs that were encoded for later enactment as compared to action verbs that were encoded for later verbal report, indicated by a reduction of recognition latencies and an increase in recognition as well as in free recall hits for to-be-enacted in comparison to to-be-reported action verbs. These findings are particularly interesting with regard to the reported extinction of the intended enactment effect in young and old adults when both to-be-enacted and to-be-reported actions are enacted during encoding (Freeman & Ellis, 2003a, b). It points again to the role of motor preparatory processes for the intended enactment effect. Although our participants were presented the execution of both action types, they still had to prepare specifically the action execution of the to-be-enacted actions during encoding, whereas with enactment of both to-be-enacted and to-be-reported actions during encoding for both action types motor preparatory processes occurred.

In line with previous findings for semantically unrelated action verbs and phrases (Freeman & Ellis, 2003b; Norris & West, 1993), for all retrieval variables the memory advantage of to-be-enacted action verbs in comparison to to-be-reported action verbs was of similar size for the young and the old participants. Like in Freeman and Ellis's (2003b) and Norris and West's (1993) studies, the young participants outperformed the old participants on all retrieval measures with the exception of recognition hits, for which the difference between young and old participants just failed to reach significance. In contrast, for free recall of delayed intentions in prospective memory paradigms generally an age-invariance is observed. These conflicting findings may be explained by the greater memory load and the greater interference effects in the studies investigating the intended enactment effect as compared to prospective memory studies. In the former studies, besides the to-be-enacted actions, a similar amount of to-be-reported actions has to be encoded at the same time (in the present study 48 different actions altogether), whereas in the latter studies often only one action, albeit a complex one, has to be encoded. Moreover, with the to-be-enacted and to-be-reported actions being matched for many variables, the former procedure leads to greater interference effects. Both greater memory load (Jennings, Nebes, & Yovetich, 1990) and greater interference (Gerard, Zacks, Hasher, & Radvansky, 1991) have been demonstrated to affect free recall in old adults more negatively than in young adults.

In contrast to our previous study, we also had participants rate the familiarity, the imaginability, the concreteness, and the executability with one arm of the action verbs used in the three conditions of the experimental task. The participants rated the action verbs as highly familiar, easily to imagine, highly concrete, and very well to execute with one arm. Moreover, the statistical analyses on differences between action verbs used in these three conditions in familiarity, imaginability, concreteness, executability with one arm as well as in number of letters and syllables confirmed that the action verbs used in three experimental task conditions were well matched for all these variables. Consequently, differences in brain activation between the conditions are not caused by differences in the action stimuli employed for these conditions.

4.2.4.2. Brain regions common to both young and old participants

1) Encoding of action verbs for later report versus watching similar action stimuli

The brain regions we found specifically activated during the encoding of action verbs for later verbal report versus watching similar action stimuli, i.e., the left ventral opercular premotor cortex, the left inferior parietal lobule, and the right superior temporal gyrus, conflict with previous neuroimaging studies which reported left-lateralized prefrontal and medial temporal lobe regions to be mainly activated during encoding of verbal stimuli (for a review see Cabeza & Nyberg, 2000). These differential findings cannot be explained by the simultaneous presentation of the action videos in our study because also encoding of nonverbal stimuli seems to primarily engage (right-lateralized) prefrontal and (bilateral) medial temporal lobe regions (Cabeza & Nyberg, 2000). It may be possible that the reason for our discrepant results is that in previous neuroimaging studies object-related information was encoded, whereas in the present study action-related information was encoded. In previous neuroimaging studies, generally nouns, pictures of objects, and locations of objects were used as stimuli.

The left ventral opercular premotor cortex and the left inferior parietal lobule are generally regarded as the brain regions in which action representations are stored, generated, and accessed (for reviews see Binkofski & Buccino, 2004; Grèzes & Decety, 2001; Rizzolatti & Craighero, 2004). These functions have been ascribed to them because they are activated when similar actions are executed, prepared, imagined, observed, during learning of observed actions for later imitation, reading of action verbs (Hauk, Johnsrude, & Pulvermüller, 2004), and listening to action sentences in comparison to abstract sentences (Tettamanti et al., 2005). There seems to be a lateralization with regard to the abstractness of the action representations, with the left ventral premotor cortex and the left inferior parietal lobule to represent more abstract features of hand actions. Thus, Perani and colleagues (2001) found that during the observation of either real or virtual constructions of hand actions both the left ventral premotor cortex and inferior parietal lobule were activated, whereas the right inferior parietal lobule was only activated during the observation of real hand actions. Furthermore, the left ventral premotor cortex and inferior parietal lobule are mainly activated in tasks requiring the retrieval of action-related knowledge implicated in pictures (Canessa, 2008; Saygin, Wilson, Dronkers, & Bates, 2004) and, even more so, in action verbs (Noppeney, Josephs, Kiebel, Friston, & Price, 2005) or phrases (Saygin, Wilson, Dronkers, & Bates, 2004). This explains why during the encoding of action verbs for later verbal report (versus watching similar action stimuli) the *left* ventral opercular premotor cortex and inferior parietal lobule were differentially activated.

The right superior temporal gyrus activation may be accounted for by the presentation of the action videos. The superior temporal gyri have been found to be activated during the perception of human movements. In a meta-analysis of neuroimaging studies on the perception of different kinds of human movements, i.e., eye, mouth, hand, and whole body movements, Puce and Perrett (2003) found activations in a similar anterior area of the right superior temporal gyrus in several studies investigating brain regions involved in the perception of hand movements. This activation may have been stronger during the encoding of actions for later verbal report than during watching of similar action stimuli condition because the participants were shown 24 different actions in the first condition and only 8 different actions (three times) in the second condition.

2) Encoding of action verbs for later enactment versus later report

We found the left ventral opercular premotor cortex and the left inferior parietal lobule more highly activated during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report both in the present and in our previous fMRI study (although the ventral premotor cortex at a more superior location in the previous study). This suggest that both regions seem to be more engaged when the action verbs have to be later enacted than later verbally reported, probably because the semantic information inherent in the action verbs needs to be translated into a more detailed motor representation of the actions that later guide their execution. In addition, in both our present and our previous study, the left dorsal premotor cortex (PMd), the left precuneus, and the left post central gyrus (although in the present study not only in BA 2, but also in BA 5) were more highly activated during the encoding of action verbs for later enactment versus later verbal report.

The relevance of the latter brain regions for encoding of actions for later enactment has been demonstrated by neuroimaging studies on action imitation. In their review on such studies, Rizzolatti and Craighero (2004) found that when actions are passively observed or observed for *concurrent* imitation, the ventral premotor cortex and the inferior parietal lobule were activated, but more strongly in the imitation condition. Moreover, only when participants had to imitate the observed actions, superior parietal lobule regions, such as the precuneus and left postcentral gyrus, were activated. They suggested that this activation represents somatosensory copies of the more abstract motor representation of the to-be-imitated actions in the ventral premotor cortex and the inferior parietal lobule in preparation for their enactment. Particularly relevant with regard to the involvement of superior parietal lobule regions for encoding of actions for *later enactment* is a PET study by Decety and colleagues (1997). They presented their participants videos of hand actions with the requirement to either imitate them later or to recognize them later out of other actions. Only during the observation of actions for later imitation versus recognition, the precuneus was activated, showing that this region is indeed specifically involved in encoding of actions for later enactment, not only in encoding of actions generally. Moreover, Buccino and colleagues (2004) asked young adults to watch videos of a skilled guitar player performing guitar chords passively, or with the requirement to imitate the chords or to enact other nonchord hand actions after *a pause*. During observation of the action videos, in all conditions the ventral premotor cortex and the inferior parietal lobule were activated, but more strongly during the action imitation condition. In addition, in both conditions that required the action execution after the pause, but not during passive observation, a superior parietal lobule activation, particularly in the postcentral gyrus, was found. In the pause before action execution, the activations of the ventral premotor cortex, the inferior parietal lobule, and the superior parietal lobule increased in the imitation condition, whereas they were absent in the condition that required the execution of other than the observed hand actions. These findings support the view that the superior lobule activation reflects the generation and storage of somatosensory copies of the more abstract motor representations of the to-be-imitated actions in the ventral premotor cortex and inferior parietal lobule that later guide their enactment. Additionally, Buccino and colleagues found the PMd only activated during action observation and in the pause before action execution when participants were required to imitate the observed actions. They suggested that the role of the PMd is to prepare the execution of the to-be-imitated actions according to the somatosensory copies of the observed actions.

Consequently, the left ventral and dorsal premotor cortices, the inferior parietal lobule, the precuneus, and the left postcentral gyrus seem to form the neural basis for the memory advantage observed for action verbs encoded for later enactment in comparison for later verbal report. Although requiring more rigorous experimental testing, the left ventral premotor cortex and inferior parietal lobule probably translate the semantic information inherent in the action verbs into motor representation of the to-be-enacted actions. Somatosensory copies of these rather abstract action representations are produced in the precuneus and postcentral gyrus, whereas the dorsal premotor cortex prepares action execution according to these somatosensory actions. In line with the requirement in our studies that the actions had to be enacted with the right hand, only the left precuneus, postcentral gyrus, and dorsal premotor cortex were activated. Additionally, these regions seem to store this information for later action enactment.

In addition to these brain regions, we found the left ventral opercular premotor cortex, the left pre-SMA, the right parahippocampal gyrus/hippocampus, and widespread bilateral occipito-temporal regions to be more highly activated during the encoding of action verbs for later enactment in comparison to the encoding of actions verbs for later verbal report, whereas in our previous study the left posterior middle temporal gyrus was additionally more activated. These differences in brain activation between our present and our previous study are probably caused by the additional presentation of videos showing the enactment of the to-be-encoded action verbs in the present study. This modification was irrelevant for encoding of action verbs for later verbal report, but may have affected the task demands during encoding of action verbs for later enactment. For this condition, the presentation of action videos prompted the participants to imitate the actions shown in the action videos (although this was not required) and, thus, to encode visuo-spatial properties of the observed actions. In contrast, the sole presentation of action verbs in our previous study probably placed greater demands on the retrieval of action-related knowledge implicated in the action verbs.

According to the review of Picard and Strick (2001) on premotor regions, the general function of the pre-SMA is to process, encode, and retrieve sensory information *relevant* for action selection or production. They reported that the pre-SMA was particularly involved in the encoding and retrieval of associations between different visual or auditory cues and specific action sequences in comparison to the encoding and retrieval of pure complex action sequences. Consequently, the left pre-SMA might have been activated in our present study during the encoding of action verbs for later enactment versus later verbal report because only for the to-be-enacted actions the additional visual information about the action verbs shown in the videos was *relevant* for later action execution, i.e., had to be encoded to guide later action imitation. In line with this suggestion of the function of the pre-SMA during the encoding of actions for later enactment in the present study are following findings on action imitation. Using fMRI, Frey and Gerry (2006) measured brain activation while young adults watched videos showing the hands of a human actor assembling small objects from six parts with the task to later imitate these actions and watched videos of the same objects being disassembled without any additional requirement. Only during the encoding of the actions for later imitation in comparison to the passive observation condition, the pre-SMA was bilaterally activated. Also in Buccino and colleagues' (2004) study, the pre-SMA was bilaterally activated during observation of action videos just when the participants had to imitate the actions later, but not when they were to enact other actions later or watched them without any further requirement. Moreover, in Decety and colleagues (1997) study, the pre-SMA was specifically activated when videos of hand actions were observed with the task to later imitate them and not when they were watched with the task to later recognize them out of other actions. Consequently, like in our present study, the pre-SMA was only activated when *visual* action presentations had to be *encoded* (versus just watched or watched with the requirement to enact other actions) *for later enactment* (versus just for later recognition).

Bilateral occipito-temporal regions and the right parahippocampus/hippocampus are known to be involved in encoding of visuo-spatial properties of stimuli (for reviews see Burgess, Maguire, & O'Keefe; Cabeza & Nyberg, 2000). The previously described studies by Frey and Gerry (2006) and Buccino and colleagues (2004) indicate that these regions are also involved in encoding of visuo-spatial properties of *action* stimuli. Both groups had included a rest condition in addition to their various action observation conditions in their studies. Compared to the rest condition, they found a similarly widespread bilateral occipito-temporal activation in all their action observation conditions. Moreover, these regions were more highly activated when the participants were required to later reproduce the observed actions compared to the other observation conditions. Additionally, Frey and Gerry (2006) also reported both hippocampi to be specifically activated while their participants observed actions videos with the requirement to imitate them later in comparison to passive observation. This explains why the bilateral occipito-temporal regions and the right parahippocampus / hippocampus were more highly activated during the encoding of action verbs for later enactment versus later verbal report in the present study: they probably processed and encoded visuo-spatial properties of the actions presented in the videos for later imitation.

The left posterior middle temporal gyrus has been found to be activated specifically in tasks involving the retrieval of action-related in comparison to other types of knowledge about objects such as size (Phillips, Noppeney, Humphreys, & Price, 2002), colour (Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995), or context (Canessa et al., 2008). Furthermore, it has been activated during semantic processing of words and sentences describing actions as opposed to other word and sentence classes (Kable, Lease-Spellmeyer, & Chatterjee, 2002; Noppeney, Josephs, Kiebel, Friston, & Price, 2005; Tettamanti et al., 2005). Therefore, the specific activation of the left middle temporal gyrus in our previous fMRI study during the encoding of action verbs for later enactment versus later verbal report seems to be caused by the higher demand on the retrieval of action-related knowledge about the to-be-enacted action verbs when they are presented alone.

4.2.4.3. Age differences in brain activation

1) Encoding of action verbs for later enactment versus later report

Although the memory advantage for action verbs encoded for later enactment in comparison to action verbs encoded for later verbal report was of similar size for our young and old participants in all retrieval measures, we found age differences in the brain activation during the encoding of the to-be-enacted versus the to-be-reported action verbs. The old participants activated the right inferior parietal lobule and the right dorsomedial prefrontal cortex more than the young participants, while the young participants activated the right caudate body more than the old participants. These brain regions were not part of the network of brain regions we found commonly more activated by both young and old participants during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report. This indicates that both young and old adults activated the brain regions that form the neural basis of the intended enactment effect to a similar degree, but additionally recruited different brain regions.

The higher activation of the right inferior parietal lobule in the old adults is in line with neuroimaging studies on age differences in brain activation during encoding of verbal materials (for a review see Park & Gutchess, 2005). Later retrieval of verbal stimuli seems to depend on the activation of the left prefrontal cortex during their encoding. Old adults, even when they show equal retrieval performance as young adults, tend to additionally activate homologous right prefrontal regions. Since the left inferior parietal lobule was more activated by both the young and old participants during the encoding of action verbs for later enactment versus later report, the additional activation of the right inferior parietal lobule in the old participants is in accordance with this age-related pattern of additional recruitment of homologous brain regions contralateral to task-relevant brain regions. Another pattern which has emerged from neuroimaging research on aging is an age-related reduction of occipito-temporal activity coupled with an increase of frontal activity. This pattern, named the posterior-anterior shift in aging (PASA), has been demonstrated for a wide range of cognitive tasks, such as visual perception, visuospatial processing, attention, working memory, episodic memory retrieval as well as encoding (Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008; Dennis & Cabeza, 2008). In line with this seems to be the additional activation of the right dorsomedial prefrontal cortex in our old participants during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report, although we did not find a decreased activation of occipito-temporal structures, but of the right caudate body, in our old participants.

Up to now the functional relevance of the additional recruitment of homologous or generally prefrontal regions in old adults as compared to young adults is unclear. It could reflect either compensation for decreased activity in other brain regions with aging or deficits in the recruitment of task-relevant or in the inhibition of task-irrelevant brain regions. There have been studies showing a positive association of task performance and the recruitment of additional brain regions with aging, but also negative or no associations have been reported (for reviews see Dennis & Cabeza, 2008; Grady, 2008; Park & Gutchess, 2005). The additional right inferior parietal lobule activation in our old participants could be compensatory for the additional right caudate body activation in our young participants. As described before, both the right and the left inferior parietal lobule have been regarded as brain regions in which representations of actions are stored, generated, and accessed (Binkofski & Buccino, 2004; Grèzes & Decety, 2001; Rizzolatti & Craighero, 2004), and following findings suggest also a functional involvement of the right caudate body in encoding action stimuli for later enactment.

The right caudate body is part of the basal ganglia which have long been implicated in motor behaviour. More recently an involvement of the basal ganglia in implicit, but also explicit motor learning has been demonstrated (for reviews see Packard & Knowlton, 2002; Seger, 2006). Buccino and colleagues (2004) reported specific bilateral basal ganglia activation during observation of actions with the requirement to imitate these later in contrast to passive observation or observation with the requirement to enact different actions later. Similarly, Frey and Grey (2006) found a stronger bilateral basal ganglia activation (although in the globus pallidus) during the observation of actions for later imitation versus passive observation. However, in our previous fMRI study on the intended enactment effect with just young adults, we did not find a higher activation of the right caudate body during encoding of action verbs for later enactment versus later verbal report. The reason for this differential finding is probably again the simultaneous presentation of the action videos in the present study. Among the basal ganglia structures, the caudate nucleus has been found to be particularly activated in visual categorisation tasks, in which appropriate motor responses to classes of stimuli have to be learned. It specifically receives input from visual occipito-temporal regions and projects to the pre-SMA (see Seger, 2008). Thus, in the present study the function of the right caudate body for our young participants might have been to relay visuospatial properties of the actions shown in the videos to the pre-SMA in order to prepare their later action execution according to the visual model.

Since the old participants did not recruit the right caudate body, they may have used the visual information about the to-be-enacted actions shown in the videos for preparation of later action enactment to a smaller degree than the young participants. Instead, they may have rather relied on their own motor representation of the action verbs stored in the inferior parietal lobules to guide later action enactment. This would be reasonable with regard to the fact that the caudate body is among the brain regions that shrink most substantially over the lifespan (Raz et al., 2005). Moreover, a reduced connectivity between basal ganglia and motor cortices during self-initiated finger movements in old adults as compared to young adults has been found (Taniwaki et al., 2007).

When one mainly prepares later action enactment according to the translation of the semantic information inherent in the action verbs into motor representation stored in the inferior parietal lobules, a spontaneous comparison of the generated motor representations and the simultaneously available visual action presentations in the videos may occur. This is in line with findings that the right inferior parietal lobule and the right dorsomedial prefrontal lobe are specifically engaged in monitoring of congruence between one's own action plans and visually perceived actions. In a review on studies on reciprocal action imitation Decety and Chaminade (2003) found the left inferior parietal lobule to be specifically activated when participants have to imitate actions of another person and the right inferior parietal lobule to be specifically activated when participants see another person imitating their actions. In the former case the visual input from the actions of the other person have to be translated into an own action plan, in the latter case one has to detect congruence between one's own action plans and the visual input received by the actions of another person. Moreover, Schnell and colleagues (2007) demonstrated that the right dorsomedial prefrontal cortex in addition to the right inferior parietal lobule is involved in monitoring the matching between one's own action plans and visually perceived actions. They measured brain activation while participants played a video game in which they had to keep a moving car within the boundaries of a curving track. In certain blocks of the task, the control of the car was taken over by the computer and the participants had to indicate when they noticed this. In the blocks in which the participants had to monitor for congruence between their own action plans and the visual feedback about the actions in contrast to the blocks in which they alone controlled the car movement, the right dorsomedial prefrontal cortex and the right inferior parietal lobule were differentially activated. Furthermore, in a meta-analysis on neuroimaging studies on different aspects of behaviour monitoring, i.e., detection of unfavourable action outcomes, response errors, pre-response conflict, and decision uncertainty, Ridderinkhof, Ullsperger, Crone, and

Nieuwenhuis (2004) found the right prefrontal region more activated by our old participants during encoding of actions for later enactment to be particularly involved in pre-response conflict. This refers to situations which activate more than one response. Such a situation occurs when the preparation of an action via motor information inherent in action verbs coincides with a visual presentation of a similar action by another person.

2) Encoding of action verbs for later report versus watching similar action stimuli

We also found age-differences in the brain activation during the encoding of action verbs and videos for later verbal report versus watching similar action stimuli. The old participants showed a higher activation than the young participants bilaterally in the posterior cingulate/retrosplenial cortex, parahippocampal gyrus, in the left fusiform gyrus, and in two regions in the right cuneus. The young participants did not activate any brain regions higher than the old participants.

The brain regions activated more highly by the old as compared to the young participants were not part of the network of brain regions we found commonly more activated by both young and old participants, i.e., the left ventral opercular premotor cortex, the left inferior parietal lobule, and the right superior temporal gyrus. This indicates that both young and old participants activated these brain regions to a similar degree, but that the old additionally recruited other brain regions. With regard to the poorer recognition and recall performance of the old as compared to the young participants for the to-be-reported action verbs, this finding is intriguing and suggests that this additional brain activation is rather task-irrelevant. Since the simultaneous presentation of action videos was irrelevant for the encoding of action verbs for later verbal report and old adults have been demonstrated to have a deficit in inhibiting irrelevant information (Hasher & Zacks, 1988), the additional brain regions activated in the old participants may be related to a greater encoding of the visuospatial properties of the action pantomimes presented in the videos or to a more elaborate processing of the action videos with regard to their semantic matching between the action verbs and their pantomimes in the videos.

A similar network of brain regions as the one more highly activated by our old participants during the encoding of action verbs and videos for later report versus watching similar action stimuli is involved in the encoding of one’s own motion in real or virtual environments (for reviews see Burgess, Maguire, & O'Keefe, 2002; Maguire, 2001), suggesting it may also encode the hand movements presented in the action videos. Additionally, this network of brain regions was more activated during observation of videos with normal action sequences as compared to random sequences (Anderson, Fite, Petrovich, & Hirsch, 2006), indicating they are involved in extracting rather abstract meaning from these videos. Similarly, the brain regions are also more activated during listening or reading of sentences referring to a person's or object's motion in concrete versus abstract settings (Wallentin, Ostergaard, Lund, Ostergaard, & Roepstorff, 2005), indicating their involvement in an analysis of verbal stimuli with regard to information about movement. Taken together, these last two findings may explain the additional activation of the bilateral posterior cingulate gyri/retrosplenial cortices, parahippocampal gyri, the left fusiform gyrus, and the right cuneus of the old participants by a more elaborate analysis of the matching between the content of the action verbs and videos.

4.2.4.4. Summary and outlook

With the present study, we tried to extend our earlier finding that brain regions known to be involved in covert motor preparation are differentially activated during the encoding of action verbs for later enactment as compared to the encoding of action verbs for later verbal report in two ways. Firstly, in addition to a group of young healthy adults we included a group of old healthy adults in the present study in order to investigate age differences in brain activation during this task. Secondly, we modified the paradigm of our previous study slightly in order to suppress the differential imagery of to-be-enacted in comparison to to-be-reported actions we had observed in our previous study. This was done by showing simultaneously to the action verbs videos of a human actor pantomiming the respective actions. As a consequence of this modification, we replaced the former condition of encoding of abstract verbs for later report with a condition that required the participants to just watch similar action verbs and videos as used in the other two conditions.

With this new paradigm, we could still demonstrate a memory advantage of to-be-enacted actions as compared to to-be-reported actions. This memory advantage was of similar size for both our young and old participants. Moreover, most of the brain regions we had found to be more highly activated during the encoding of action verbs for later enactment versus later verbal report in our previous study were also more activated in the present study and, therefore, seem to be the neural basis of the intended enactment effect. Specifically, these brain regions were the left ventral premotor cortex, the left dorsal premotor cortex, the left inferior parietal lobule, the left precuneus, and the left postcentral gyrus. By reviewing neuroimaging studies particularly on action imitation, we suggested how these brain regions act together during encoding in order to prepare later execution of the presented action verbs.

With reference to earlier neuroimaging findings, we could also explain differences in brain activation between our previous and the present study during encoding of action verbs for later enactment as opposed to the encoding of actions for later verbal report. The additional activation of the left pre-supplementary motor area, the right parahippocampus / hippocampus, and bilateral occipito-temporal regions in the present study is most likely related to an additional encoding of visuospatial properties of the to-be-enacted actions presented in the videos in order to guide their later execution. In contrast, in the previous study the sole presentation of action verbs placed greater demands on the retrieval of action-related knowledge about the to-be-enacted actions and, thus, led probably to the additional engagement of the left posterior middle temporal gyrus.

However, it still remains unclear whether the additional presentation of the action videos indeed led to the total suppression of the differential imagery of the to-be-enacted actions in comparison to the to-be-reported actions. Although the presentation of pantomimes of both action types in the videos certainly reduced the amount of differential imagery of the to-be-enacted actions in comparison to the to-be-reported actions, for the to-be-enacted actions one may still be more inclined to visualize how one would enact the actions one-self later on. In order to investigate the extent to which the brain regions we found to be more activated during the encoding of actions for later enactment versus later verbal report are engaged in differential imagery of or in “pure” motor preparatory processes for the to-be-enacted actions, another modification of our original paradigm may be more successful. In a follow-up study, it would be useful to ask the participants directly to imagine the execution of both the to-be-enacted and the to-be-reported actions during encoding and see whether similar brain regions as in our two fMRI studies are specifically activated when the encoding of to-be-enacted actions is contrasted to the encoding of to-be-reported actions. On the other hand, since the imagery of the to-be-enacted action verbs seems to occur spontaneously, it could be regarded as part of the preparatory processes for later action execution.

During the encoding of action verbs (and videos) for later verbal report in contrast to watching similar action stimuli, we found other brain regions than those normally reported to be engaged in encoding of verbal as well as nonverbal stimuli to be specifically activated. Since previous neuroimaging studies on encoding mainly required the encoding of object-related information (e.g., nouns referring to objects, pictures, and locations of objects), this differential finding may be explained by the requirement to encode action-related information in our study. It would be interesting to see whether a similar dissociation in brain regions could be found during the encoding of object- in contrast to action-related information about similar stimuli. For the retrieval of action-related knowledge about objects in comparison to the retrieval of knowledge about their size (Phillips, Noppeney, Humphreys, & Price, 2002) or colour (Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995) activation of differential brain regions has already been demonstrated.

Although the memory advantage for the to-be-enacted actions in comparison to the to-be-reported actions was of similar size for both our young and old participants, we still found age-differences in brain activation during the encoding of actions for later enactment as compared to the encoding of actions for later verbal report. In addition to the brain regions both participant groups engaged commonly for this task, the young adults activated the right caudate body and the old participants the right inferior parietal lobule and the right dorsomedial prefrontal cortex. This may reflect a reliance on differential strategies for action preparation in young and old age. The young adults may have relied to a greater extent on the visual action presentation in the videos transmitted through the right caudate body to prepare their later execution. In the light of a substantial age-related loss of caudate body volume and connectivity, the old adults may have relied more on motor representations of the action verbs stored in the parietal inferior lobules in order to prepare their later enactment. The strategy of the old adults has the consequence that the action videos are analysed for congruence with these internal action representations. The right inferior parietal lobule and the right dorsomedial prefrontal cortex have been shown to be specifically engaged in analyses of congruence between one own's action plans and visual action presentations.

We also found age differences in brain activation during the encoding of action verbs for later verbal report in comparison to watching similar brain regions. For this contrast, only the old participants activated more brain regions in addition to those commonly activated by all participants. The worse retrieval performance for the to-be-reported actions of the old as compared to the young participants suggests that this additional recruitment of brain regions by the old participants is most likely task-irrelevant. The brain regions additionally recruited by the old participants, i.e., the bilateral posterior cingulate/retrosplenial cortex and parahippocampus, the left fusiform gyrus, and the right cuneus, have been demonstrated to be involved in the encoding or in elaborate processing of movement-related stimuli. Therefore, during the encoding of action verbs for later report, the old participants may have engaged in task-irrelevant encoding or elaborate analysis of the visuospatial features of the actions presented in the action videos.

We have explained the age-differences in brain activation during both encoding of action verbs for later enactment versus later report and encoding of action verbs for later report versus watching similar action stimuli with age-differences in the handling of the simultaneous presentation of action verbs and videos. Therefore, in a follow-up study it would be interesting to see whether the age-differences in brain activation we found in the present study disappear when action verbs would be presented to young and old participants alone.

In both the present and our previous fMRI study, we had asked the participants to encode actions for later enactment with the right arm only. In both studies we found a network of left-lateralized brain regions to be differentially activated during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report. The left ventral premotor cortex and inferior parietal lobule may be involved in the translation of the action verbs into motor presentations. However, it is unclear whether the left dorsal premotor cortex, the left precuneus, and the left postcentral gyrus were activated because they are contralateral to the arm the actions had to be later executed with or are generally involved in motor preparation. To resolve this issue, it would be interesting to measure brain activity when participants encode action verbs for later enactment with the left instead of the right arm.

Taken together, our findings suggest that the memory advantage of verbal descriptions of actions encoded for later enactment in comparison to verbal descriptions of actions encoded for later report seems to be based for both young and old adults on the activation of brain regions known to be involved in action preparation, although small age differences in brain activation exist. Therefore, our findings support the proposal of Freeman and Ellis (2003a) that motor preparatory processes seem to be the basis for the intended enactment effect and the age invariance in free recall for delayed intentions reported in prospective memory research.

5. Study 4: Self-Reported Everyday Prospective versus Retrospective Memory Competence in Old Healthy Adults, Patients with Mild Cognitive Impairment, and Patients with Mild Alzheimer's Disease[3]

5.1. Introduction

With growing life expectancy, Alzheimer's disease (AD) has become a major health challenge for industrialized countries (Sloane et al., 2002). Clinical diagnosis of AD requires the presence of multiple cognitive deficits and impairment of everyday functioning (see fourth edition of the Diagnostic and Statistical Manual for Mental Disorders, *DSM-IV*; American Psychiatric Association, 1994). This has been considered as a very late stage for possible therapeutic intervention in the neuropathological process (Reisberg & Gauthier, 2008) and, therefore, current management attempts focus on the identification of individuals in an earlier stage of the disease (Caselli, Beach, Yaari, & Reiman, 2006; Leifer, 2003).

Since cognitive decline seems to start about 10 years before clinical AD diagnosis (Almkvist et al., 1998), several diagnostic concepts have been developed to identify individuals in the transitional state between normal aging and AD characterized by cognitive impairments, but still largely preserved functional abilities (see Reisberg et al., 2008 for an overview). Among them, the diagnostic concept Mild Cognitive Impairment (MCI) as proposed by the International Working Group on Mild Cognitive Impairment (Winblad et al., 2004) seems to have lately achieved the most general acceptance. The criteria for MCI are (a) the person is neither normal nor demented, (b) there is evidence of cognitive deterioration shown by either decline in neuropsychological test performance over time and/or subjective report of decline by self and/or informant in conjunction with objective cognitive deficits as defined by neuropsychological test performance below age-adjusted norms, and (c) activities of daily living are preserved and complex instrumental functions are either intact or minimally impaired. As for AD diagnosis, other neurological, systemic, or psychiatric diseases, or regular use of substances known to cause for cognitive dysfunction have to be excluded.

Individuals with MCI are now widely used as a target group for research on pharmacological (Raschetti, Albanese, Vanacore, & Maggini, 2007) and cognitive (Belleville,

[3] A similar version of this chapter has been submitted to *Brain Impairment* as Eschen, A., Martin, M., Schreiter Gasser, U., & Kliegel, M. Prospective and retrospective memory complaints in Mild Cognitive Impairment and Mild Alzheimer's disease.

2008) intervention methods for AD. However, this has been criticized because MCI seems to be a heterogeneous entity (Allain, Bentué-Ferrer, & Akwa, 2007; Rockwood, Chertkow, & Feldman, 2007). Although there is a markedly higher incidence of AD in individuals with MCI as compared to the general population (Petersen & Negash, 2008), a rather high percentage develops other dementias, remains stable, or even reverts to a cognitively intact status (Ganguli, 2006). Furthermore, incidence of MCI and conversion rates to AD vary between different studies (Bruscoli & Lovestone, 2004; Panza et al., 2005), caused by differences in populations being studied (i.e., clinic attenders versus normal population) and in specific operationalization of MCI criteria. In fact, studies vary widely in definition and assessment of cognitive impairments and complaints, i.e., which cognitive domains are assessed with which tests, questionnaires, or interviews, which cut-off score (1, 1.5, or 2 standard deviations below age-adjusted norms) is used for determination of impaired test performance. Therefore, a need to refine diagnostic criteria for MCI has been recognized (Mariani, Monastero, & Mecocci, 2007; Thompson & Hodges, 2002).

For cross-sectional diagnostic assessment of MCI, the International Working Group on Mild Cognitive Impairment recommended a stepwise procedure. For the first step, they suggested the examination of the presence of cognitive complaints by the person assessed or a close acquaintance of this person, then the assessment of functional and cognitive abilities. Since information from an acquaintance takes time and might be difficult to acquire, the question arises whether for screening for MCI it would be useful to initially assess the subjective cognitive complaints of the old adults themselves.

For such a screening to be useful, it should help to distinguish MCI patients from healthy old adults without cognitive impairments and intact everyday functioning as well as from mild AD patients with severe multiple cognitive deficits and impaired functional abilities. With regard to the discrimination from healthy old adults, findings from studies with elderly non-demented population-based samples (Fisk, Merry, & Rockwood, 2003; Fisk & Rockwood, 2005; Jungwirth et al., 2004; Luck, Busse, Hensel, Angermeyer, & Riedel-Heller, in press; Purser, Fillenbaum, & Wallace, 2006) question the usefulness of an initial screening for subjective cognitive impairments for MCI diagnosis. In these studies subjective cognitive complaints were assessed with the help of a single question regarding everyday memory impairment. They demonstrated that about as many people with cognitive impairments and largely preserved everyday functioning complained about everyday memory impairment as not. Furthermore, many people with normal cognitive abilities and preserved functional abilities also complained about an everyday memory deficit. Also among non-demented elderly people with normal everyday functioning who consulted a memory clinic for dementia assessment and complained in a clinical interview about memory impairment (Sinforiani, Zucchella, & Pasotti, 2007), many showed normal cognitive abilities as evaluated by an extensive neuropsychological examination.

However, the method of assessing subjective cognitive complaints by just one question about everyday memory seems to be inappropriate with regard to its specifity and sensitivity for MCI. Since normal aging is associated with mild cognitive decline and cognitive impairments of MCI patients are defined by neuropsychological test performance below age-adjusted norms, many old adults will judge their everyday memory as impaired. On the other hand, since MCI patients do not show impairments in most aspects of everyday functioning, many of them will judge their overall everyday memory as largely preserved. Therefore, a screening instrument for subjective complaints should rather include several questions regarding different aspects of everyday cognitive functioning and differences between MCI patients and healthy old adults should arise in their level of positive answers or ratings. The same holds true for the differentiation between MCI and mild AD patients, because by definition they also differ in their level, not in the presence, of cognitive and functional impairment.

Indeed, several studies using questionnaires or interviews about everyday impairments in memory (Clément, Belleville, & Gauthier, 2008; De Jager & Budge, 2005; Perrotin, Belleville, & Isingrini, 2007) or in several cognitive domains (Kliegel, Zimprich, & Eschen, 2005; Rabin et al., 2006) have demonstrated that MCI patients report a higher level of subjective cognitive complaints than healthy old adults, but a similar level of subjective memory (Clément et al., 2008) and general cognitive complaints (Kalbe et al., 2005) as mild AD patients.

These findings have been explained with the diminished insight of the mild AD patients in their cognitive deficits. For mild AD patients, it has been demonstrated that on cognitive questionnaires they evaluate their cognitive abilities as more positive than their carers (Cahn-Weiner, Ready, & Malloy, 2003; Derousné et al., 1999). Kalbe and colleagues (2005) had asked caregivers of their MCI and mild AD patients to rate the patients' cognitive abilities. In comparison with their carers, the mild AD patients indeed underreported their cognitive deficits, while the MCI patients actually overreported their cognitive impairments. In contrast, Vogel, Hasselbach, Gade, Ziebell, and Waldemar (2005) reported that compared to their family members and friends, both MCI and mild AD patients showed a similar degree of underreporting of memory impairments, while the ratings of old healthy adults and their close acquaintances were very alike. These differential findings on insight in MCI patients might be caused by differences in the instruments used. Kalbe and colleagues questioned their participants on various cognitive abilities, while Vogel and colleagues used a memory questionnaire only, suggesting that MCI and mild AD patients have a diminished insight for this cognitive ability only. This is surprising, since among preclinical cognitive impairments of AD, episodic memory impairment has proven to be one of the earliest and best predictors of later diagnosis (Almkvist, 1996; Bäckman, Jones, Berger, Laukka, & Small, 2005; Rubin et al., 1998) and all MCI patients in Vogel and colleagues' study had a severe impairment in this cognitive domain only (two standard deviations below age-corrected norms). Kalbe and colleagues, however, did not find significant differences between the MCI and AD patients' and their caregivers' ratings for their memory question, but as mentioned before, using only one question to assess everyday memory might not be sensitive enough to find differences between groups that differ only in their level of impairment. Clément, Belleville, and Gauthier (2008) actually reported that although their MCI and mild AD patients had similarly higher sum scores on an everyday memory questionnaire than their healthy old adults, the AD patients had significantly higher scores than the healthy old adults on only 3 of 10 subsections of the questionnaire. Those sections referred to memory for films and books, conversations, and places. In contrast, MCI patients additionally had significantly higher scores than the healthy old adults on three other subsections relating to memory for personal events, learning difficulties, and working memory. These findings seem to suggest, that only questionnaires on certain types of everyday memory impairments might be useful to discriminate between healthy old adults, MCI patients, and mild AD patients in an initial screening.

Research on episodic memory impairment as an early indicator of AD has so far mainly concentrated on one of its domains, i.e., retrospective memory, whereas another, i.e., prospective memory, has been largely neglected. While retrospective memory relates to remembering *past* events, prospective memory refers to remembering to carry out planned actions at a pre-specified times in the *future* (McDaniel & Einstein, 2007). Prospective memory has a *retrospective component* (remembering which actions were intended for later execution at what times), but involves distinct processes (termed *prospective component*) that enable the recognition of the pre-specified execution times, the subsequent retrieval and execution of the planned actions (for verification of discriminant validity of prospective versus retrospective memory see Salthouse, Berish, & Siedlecki, 2004 and Zeintl, Kliegel, & Hofer, 2007). Among these distinct processes, executive functions, such as monitoring for the pre-specified times while performing other activities, inhibition of the ongoing activities, and initiating the planned actions at the critical times, seem to play a leading role (for detailed task analyses see Burgess & Shallice, 1997; Ellis, 1996; Knight, 1998; for evidence on greater involvement of executive functions versus retrospective memory see Kopp & Thöne-Otto, 2003; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999).

Based on their finding that people with very mild dementia have greater prospective than retrospective memory deficits, Huppert and Beardsall (1993) were the first to suggest that prospective memory is a more sensitive indicator of early dementia than retrospective memory. However, Maylor (1995) questioned their findings because she regarded their prospective memory task as improper. Using an appropriate prospective memory task in a large population-based elderly sample, Huppert, Johnson, and Nickson (2000) could demonstrate a markedly higher prevalence of prospective memory impairments in participants with mild dementia than in healthy participants. Although their mildly demented participants showed a profound impairment of the retrospective component of the prospective memory task, the impairment of its prospective component was even greater, supporting the notion of prospective memory being a better indicator of early dementia than its retrospective counterpart. The findings of Huppert and colleagues are, however, unspecific for AD, since their mild demented samples included people with all types of dementias.

Maylor, Smith, Della Sala, and Logie (2002) found that individuals with *mild to moderate AD* performed worse than healthy elderly controls on prospective memory tasks, but were even more impaired on retrospective memory tasks. Surprisingly, the retrospective component of the prospective memory task was intact in all their AD patients. Duchek, Balota, and Cortese (2006) also demonstrated a clear prospective memory deficit relative to healthy controls in a group of old adults with *very mild AD*. The authors did not directly compare the prospective with the retrospective memory performance of their participants, but demonstrated that the prospective memory performance helped to discriminate between the very mild AD patients and healthy adults above and beyond retrospective memory performance. Moreover, within their prospective memory task, the impairment of the prospective component was greater than that of the retrospective component. Finally, in a large longitudinal population-based study, Jones, Livner, and Bäckman (2006) found that compared to participants who remained healthy, participants who *three years later received an AD diagnosis* showed deficits in prospective and retrospective memory and that these were of equal size. Additionally, the impairments of the retrospective and the prospective component of the prospective memory task were similar. Retrospective memory performance alone best predicted later AD diagnosis, but prospective memory performance additionally improved prediction accuracy. In summary, these findings indicate that although prospective memory is not a better marker than retrospective memory of preclinical or early AD than retrospective memory, it seems to be equally sensitive, and assessment for both types of episodic memory improves discrimination of preclinical and mild AD patients from healthy old adults.

With regard to *subjective* memory complaints, prospective memory complaints may have a higher discriminative power than retrospective memory complaints for a screening for MCI. Mäntylä (2003) suggested that people have a greater insight in their prospective than their retrospective memory competence because prospective memory involves more conscious, self-initiated (i.e., executive) behaviour. Furthermore, awareness of prospective memory failures should be greater than awareness for retrospective memory failures, since prospective memory failures seem to cause a greater impairment in everyday functioning (Kliegel & Martin, 2003) and have more negative social consequences than retrospective memory failures, because they are attributed to a person's lack of reliability, whereas retrospective memory failures are mostly ascribed to a weakness of a person's memory (Winograd, 1988).

Smith, Della Sala, Logie, and Maylor (2000) have developed a questionnaire specifically designed to capture differences between subjective prospective and retrospective memory complaints, named the Prospective and Retrospective Memory Questionnaire (PRMQ). The PRMQ has two subscales: the Prospective Scale consists of eight questions relating to everyday prospective memory failures and the Retrospective Scale consists of eight questions regarding everyday retrospective memory failures. A great advantage of the PRMQ is that it is theory based: the questions for everyday prospective and retrospective memory failures are matched for two other important dimensions of episodic memory (i.e., self- versus environmentally-cued retrieval and length of retention interval). Confirmatory factor analyses on the PRMQ items in a large British (Crawford, Smith, Maylor, Della Sala, & Logie, 2003) and in a large Swedish (Rönnlund, Mäntylä, & Nilsson, 2008) population-based sample have indeed proven a three-factor structure of the PRMQ with the Prospective and Retrospective Scale as orthogonal factors and episodic memory as a common factor. These studies also confirmed a high internal consistency of both scales. Additionally, concurrent validity of the Prospective Scale has been demonstrated: in healthy middle-aged (Mäntylä, 2003) and old adults (Kliegel & Jäger, 2006), performance on laboratory prospective memory tasks was correlated to the Prospective Scale only. Moreover, Mäntylä (2003) could provide evidence that the Prospective Scale is indeed related to everyday prospective memory performance. He demonstrated that middle-aged women who specifically regarded their prospective memory as poor had higher scores than middle-aged women who considered their memory generally as intact only on the Prospective Scale of the PRMQ. Additionally, the complaining women performed equally well as the non-complaining women on classical retrospective memory tasks, but were slightly impaired on laboratory and severely impaired on naturalistic prospective memory tasks.

With the PRMQ, Mäntylä's proposal of a greater awareness for prospective than for retrospective memory failures could be confirmed by the finding that in the normal population average Prospective Scale scores are higher than Retrospective Scale scores (Crawford et al., 2003; Kliegel & Jäger, 2006; Mäntylä, 2003; Rönnlund et al., 2008; Smith et al., 2000; with the only exception of Singer, Falchi, MacGregor, Clerkas, & Spector, 2006). Furthermore, Singer and colleagues (2006) could demonstrate the specific involvement of executive functions in everyday prospective memory. They reported that in a large sample of twins aged between 19 and 85 years the Prospective Scale of the PRMQ was not related to performance on classical retrospective memory tasks, but to working memory performance only. For AD patients, however, Smith and colleagues (2000) did not find that the Prospective Scale of the PRMQ discriminated them better from healthy old adults than the Retrospective Scale; instead both scales had a similar discriminative power. Nevertheless, Smith and colleagues had asked the carers of AD patients to complete the PRMQ on the patients' behalf and the objectivity of the carers' judgement was questioned by the finding that the carers evaluated their own everyday prospective and retrospective memory better than age-matched healthy control participants.

Therefore, the first aim of this study was to evaluate the usefulness of subjective prospective versus retrospective memory complaints for discriminating MCI patients from healthy old adults and mild AD patients by comparing the ratings of a group of healthy old adults, a group of individuals with a clinical diagnosis of MCI, and of a group of individuals with a clinical diagnosis of mild AD on the Prospective Scale and on the Retrospective Scale of the PRMQ. It was anticipated that all participant groups complain more about prospective than retrospective memory failures. MCI patients were expected to report more prospective and retrospective memory failures than the healthy old adults, while the AD patients were expected to report more prospective memory failures than the MCI patients, but a similar amount of retrospective memory failures.

The second aim of this study was to evaluate the appropriateness of Mäntylä's claim that insight in everyday prospective memory competence is specifically related to executive functioning and whether this applies to healthy old adults as well as to individuals with MCI for whom insight in their memory competence has been questioned by Vogel and colleagues' findings. This was done by calculating correlations between the scores of the healthy old adults or MCI patients, respectively, on the PRMQ Prospective and Retrospective Scale and on three executive function tests. Since it has been demonstrated that age, education, gender, and depressive affect are related to subjective memory complaints in normal aging (Jonker, Geerlings, & Schmand, 2000; Zimprich, Martin, & Kliegel, 2003) and MCI patients (Kliegel, Zimprich, & Eschen, 2005), correlations between these variables and the Prospective and Retrospective Scale scores were also computed seperately for both participant groups and, if applicable, controlled for. It was expected that for both the healthy old adults and the MCI patients, their executive function test scores are correlated to their scores on the Prospective Scale, but not to the Retrospective Scale of the PRMQ.

5.2. Method

5.2.1. Participants

In total, 107 participants were included in the analyses: 27 MCI patients, 9 patients with mild AD, and 71 healthy old controls.

5.2.1.1. MCI and AD patients

MCI and AD patients were recruited out of 311 in- and outpatients of the Gerontopsychiatric Centre of the Psychiatric University Hospital Zurich who underwent a neuropsychological examination as part of an extensive diagnostic assessment for self- or informant-reported cognitive decline between July 2003 and June 2005 for the first time. At the end of the neuropsychological examination, patients who were not handicapped by too severe perception, language, or comprehension impairments were asked to complete the PRMQ. In total, 101 patients were able to and agreed to fill out the questionnaire.

The neuropsychological test battery (see below) contained a depression screening questionnaire and tests for the cognitive domains memory, language, praxia, perception, executive functions, attention, speed, and crystallized intelligence. Cognitive impairment was operationalized by test performance of at least one standard deviation below age-adjusted norms, since MCI diagnosis based on this cut-off score has been found to have the highest predictive power for later development of dementia (Busse, Hensel, Gühne, Angermeyer, & Riedel-Heller, 2006). In addition to the neuropsychological examination, a clinical interview with the patient and a person who knew the patient well was conducted to determine the patient's level of functional ability, to evaluate the presence of psychiatric disorders including substance abuse, and to obtain a medical history. The medical history was corrobated by and complemented with relevant previous medical reports about the patient. Furthermore, a neurological, a neuroradiological (either computer tomography or magnetic resonance imaging), and a laboratory examination were conducted to screen for neurological and systemic diseases known to cause cerebral dysfunction.

Based on these assessments, out of the 101 patients who completed the PRMQ, 9 received the diagnosis of a probable AD according to the *DSM-IV* (American Psychiatric Association, 1994) and the NINCDS-ADRA criteria (McKhann et al., 1984), and 27 received the diagnosis of MCI according to the general MCI criteria as proposed by the International Working Group on Mild Cognitive Impairment (Winblad et al., 2004). All AD patients were in the mild stage of the disease as indicated by MMSE scores greater than 17 and by their individual neuropsychological profiles, i.e., their cognitive impairments were restricted to memory, naming, executive functions, and constructional praxia deficits (Ballard et al., 1999, Storey, Slavin & Kinsella, 2002). As AD, MCI was only diagnosed when there was no evidence for neurological and systemic diseases, psychiatric disorders, or substance abuse that could account for the cognitive deficits. The remaining 65 patients who completed the PRMQ were excluded from the analyses for the following reasons: 1 did not complete the whole assessment procedure, 3 showed normal test performance, 1 had a schizoaffective disorder, 16 for indication of a depressive episode (either by clinical diagnosis or by the scores on the depression screening questionnaire), 10 for alcohol abuse, 3 for epilepsy, 1 for a traumatic brain injury, 1 for a subdural hematoma, 12 for strokes or cerebrovascular haemorrhages, 2 suffered from a subcortical vascular dementia, 11 from a mixed dementia, and 4 from Parkinson's Disease. Figure 11 shows a schematic overview of the diagnostic procedure for the MCI and the mild AD patients.

5.2.1.2. Healthy old controls

Altogether 80 community dwelling old adults aged between 54 and 91 years (in order to match for the typical patient age range of the Gerontopsychiatric Centre) were recruited as controls. They were screened with the help of a specifically designed health questionnaire and a depression screening questionnaire (see below) for the same exclusion criteria that were applied for the diagnosis of the MCI and AD patients: regular use of neurotoxic substances or neurological, psychiatric, and systemic diseases known to cause cognitive dysfunction. With this procedure, nine participants were excluded: five for indication of alcohol abuse and four for indication of a depressive episode (either by relevant information from the health questionnaire or by the scores on the depression screening questionnaire).

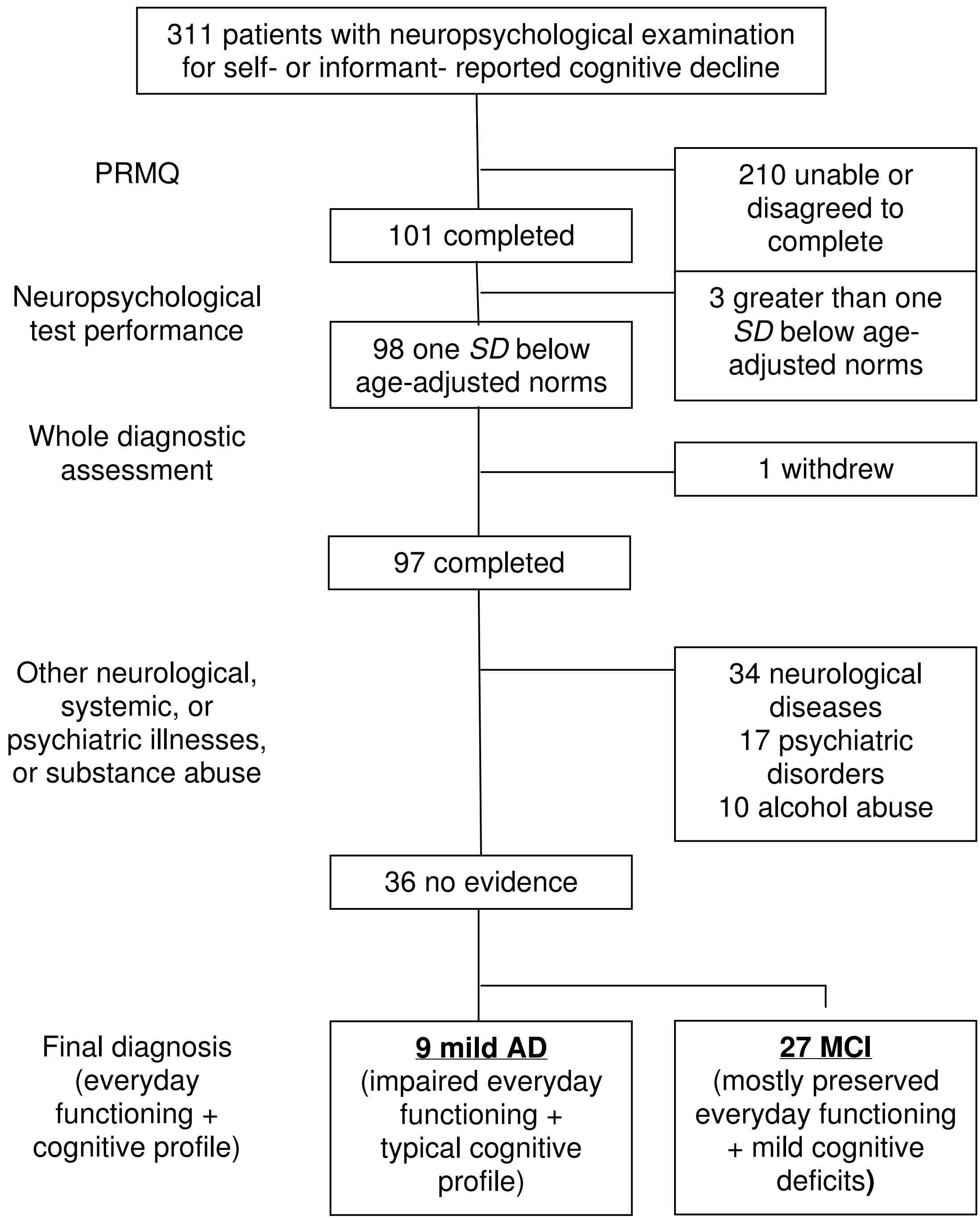

***Figure 11*. Selection Procedure for the MCI and the Mild AD Patients.**

5.2.2. ***Materials***

5.2.2.1. Depression screening questionnaires

1) MCI and AD patients

The short form of the Geriatric Depression Scale (GDS; Sheikh & Yesavage, 1986) was used to screen for the presence of a depressive episode among the patients. This 15-item self-report questionnaire was specifically developed for old adults. Since somatic depressive symptoms such as disturbance of sleep or appetite are often experienced by old adults due to somatic illnesses, the questionnaire focuses on emotional and motivational depressive symptoms. Participants have to agree or disagree to questions regarding these symptoms (e.g. "Do you feel that your life is empty?"). Answers indicative of a depressive episode are summed up. Thus, possible minimum and maximum scores are 0 and 15. Sum scores greater than 5 are considered to be suggestive, scores greater than 10 to be indicative of the presence of a depressive episode. GDS scores greater than 5 lead to exclusion from this study. All patients completed the GDS in the presence of their neuropsychologist and were thus able to ask comprehension questions.

2) Healthy old controls

The depression subscale of the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) was used to screen for presence of a depressive episode in the healthy elderly volunteers. Like the GDS, the HADS depression subscale is a self-report questionnaire that focuses on emotional and motivational depressive symptoms. It contains seven items referring to these types of depressive symptoms (e.g., "I have lost interest in my appearance"). Participants have to indicate on a four-point rating scale (*nearly all of the time, very often, sometimes, not at all*) how often these symptoms occurred in the last week. These ratings are assigned numerical values of 3 (*nearly all of the time*) to 0 (*not at all*) and summed up. Consequently, possible scores range from 0 to 21. Scores between 8 and 10 are regarded as suggestive, scores of 11 and higher as indicative of the presence of a depressive episode. In this study, scores greater than 8 lead to exclusion. All healthy volunteers completed the HADS depression subscale in the presence of the experimenter and were thus able to ask comprehension questions.

5.2.2.2. Neuropsychological tests

1) MCI and AD patients

The neuropsychological examination for the MCI and AD patients included the German version of the Consortium to Establish a Registry for Alzheimer's Disease

Neuropsychological Assessment Battery (CERAD-NAB) that was scaled on a large Swiss German sample of healthy adults aged between 53 and 92 years to provide age-, gender- and education-specific norms (Berres, Monsch, Bernasconi, Thalmann, & Stähelin, 2000). It has been proven to discriminate between healthy old adults, patients with a major depression, with MCI, with mild, and with moderate AD, respectively (Barth, Schönknecht, Pantel, & Schröder, 2005) as well as between patients with mild AD, mild frontotemporal dementia, and mild semantic dementia (Diehl et al., 2005). The CERAD-NAB contains seven subtests. One subtest is the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) which is a standard dementia screening and staging instrument. Two subtests screen for language impairments: a semantic fluency test (naming of as many animals as possible in 1 min) and a 15-item form of the Boston Naming Test. One subtest is a constructional praxia test (copying of four geometric shapes). Four subtests screen for retrospective memory deficits: a delayed free recall test for the four copied geometric patterns (constructional praxia delayed recall), a word list learning test (10 words in three trials), a delayed free recall and a delayed recognition test (10 learned words and 10 distracters) for this word list.

2) All participants

The following tests were completed by all participant groups. They were selected from the neuropsychological test battery for the MCI and AD patients, to allow for a short measurement of crystallized intelligence, short-term memory, and executive functioning (i.e., working memory, task switching, and inhibition) in the healthy old adults.

Crystallized intelligence was evaluated with the the Mehrfachwahlwortschatztest B (MWT-B; Lehrl, 1977), a multiple-choice vocabulary test. Raw scores can be converted to IQ scores. Since crystallized intelligence is thought to be a product of both formal and informal educational efforts throughout life (see Cattell, 1987), this test was used as a second measure for educational attainment next to years of schooling which reflect by definition only formal educational efforts in the youth.

Short-term memory was assessed with the Digit Span forward subtest of the German version of the Wechsler Memory Scale-Revised (WMS-R; Härting et al., 2000). Possible minimum and maximum scores are 0 and 12.

Working memory was tested with the Digit Span backward subtest of the German version of the WMS-R. Possible minimum and maximum scores are 0 and 12.

Task switching was measured with the Trail Making Test (TMT; Reitan, 1955; version and norms according to the new extended German CERAD-NAB online version "CERAD-Plus online", Memory Clinic Basel). In Part A of the TMT (TMT-A), the time (in s) was measured that the participants needed to connect randomly distributed digits (1 - 25) in ascending order. This is regarded as a measure for motor speed. In Part B of the TMT (TMT-B) the time (in s) was measured that the participants needed to alternately connect randomly distributed digits (1 - 13) and letters (A - L) in ascending or alphabetical order, respectively. In the “CERAD-Plus online”-TMT version the quotient of time for Part B and time for Part A (TMT B/A) is used as a measure for task switching, thus controlling for motor speed.

Inhibition was measured with the third plate of the Stroop-Victoria Test (Regard, 1981). The third plate depicts the words “yellow”, “red”, “blue”, and “green” (altogether 20) in the yellow, red, blue, and green with the colour of the words not corresponding to their meaning. The time (in s) was measured that the participants need to correctly state the colour of all words.

5.2.2.3. Prospective and retrospective memory complaints

For the assessment of the amount of prospective and retrospective memory complaints, all participants completed the German version of the Prospective and Retrospective Memory Questionnaire (PRMQ; Kaschel, 2002). The PRMQ contains 16 items. Eight of these items refer to everyday prospective memory failures (e.g. “Do you fail to mention or give something to a visitor that you were asked to pass on?”) and form the Prospective Scale. The 8 other items refer to everyday retrospective memory failures (e.g. “Do you fail to recognise a place you have visited before?”) and form the Retrospective Scale. On each item, the participants indicated on a 5-point Likert-type rating scale (*very often, quite often, sometimes, rarely*, and *never*) how often they have recently experienced this particular memory failure. These ratings were assigned numerical values of 5 (*very often*) to 1 (*never*) and were summed up. Consequently possible minimum and maximum scores on the Prospective and Retrospective Scales are 8 and 40. All MCI and AD patients completed the PRMQ in the presence of their neuropsychologist, all healthy old adults in the presence of the experimenter. All participants were thus able to ask comprehension questions.

5.3. Results

5.3.1. Group differences in demographic variables and depressive affect

In Table 15, the healthy old adults, the MCI and the AD patients are compared for age, gender, years of schooling, crystallized intelligence, and amount of depressive symptoms (for healthy old adults HADS depression subscale scores and for the two patients groups GDS scores). Additionally, the patient groups are compared for patient status (in- or outpatient).

Table 15. ***Comparison of the Participant Groups for Demographic Variables and Depression***

	Control (n = 71) M (SD)	MCI (n = 27) M (SD)	AD (n = 9) M (SD)
Age (years)	73.20 (7.34)	73.44 (6.84)	75.33 (6.56)
Gender	59.2 % women	70.4 % women	88.9 % women
Years of Schooling	13.30 (2.86)	12.15 (3.27)	11.11 (1.54)
Intelligence (IQ)[a]	124 (52)	107 (50)[b]	104 (15)
Depression[c]	3.08 (1.75)	2.02 (1.54)	2.22 (1.39)
Patient status[d]		88.9 % outpatients	77.8 % outpatients

Note. [a]Medians and ranges are reported since variances were inhomogeneous between groups. [b]n = 25. [c]For controls: HADS depression subscale scores (possible range 0 - 21), for MCI and AD patients: GDS scores (possible range: 0 - 15). [d]In- or outpatient.

The three groups did not differ with respect to age ($F(2, 104) = 0.36$; $p < .80$), or gender ($\chi^2(2, N = 107) = 3.63$, $p < .20$). There was a difference with respect to formal education ($F(1,104) = 3.28$; $p = .042$), with post-hoc comparisons (Tukey *a*) indicating a trend to fewer years of schooling in the AD patients as compared to the healthy old adults, HSD = -2.18, $p = .087$. A Kruskal-Wallis test with participant group as between-subject variable was used to evaluate group differences in crystallized intelligence because variance homogeneity between groups was not given. According to this analysis ($\chi^2(2, N = 105) = 28.98$, $p < .001$), the groups differed in their crystallized intelligence level. Post-hoc comparisons (independent *t* tests) indicated that the healthy old adults had a higher crystallized intelligence level than the MCI ($t(94) = 4.95$, $p < .001$) and the AD patients, $t(32.85) = 8.74$, $p < .001$. The median crystallized intelligence level of the healthy old adults was above average and that of the MCI and the AD patients approximately average, with all participants individually having at least an average IQ (minimum IQ of the whole sample was 86). This is in line with findings of higher incidence rates for MCI (Kumar, et al., 2006; Panza et al., 2005; Tervo et al., 2004) and AD (see Caamaño-Isorna, Corral, Montes-Martínez, & Takkouche, 2006 for a meta-analysis) in old adults with lower educational attainment.

Due to the strict selection procedure (exclusion of healthy old adults with scores greater than 8 on the HADS depression subscale and of MCI and AD patients with scores greater than 5 on the GDS), the amount of depressive symptoms in all participant groups was very low. An independent *t* test confirmed that the MCI and AD patients did not differ in their reported level of depressive symptoms, $t(34) = -.35$, $p < .80$. Furthermore, both patient groups did not differ in the relative proportion of in- and outpatients, ($\chi^2(1, N = 36) = 0.68$, $p < .50$), with the large majority being outpatients.

5.3.2. Group differences in neuropsychological tests

Table 16 provides the CERAD-NAB subtest scores of the MCI and the AD patients and the results of the statistical analyses for differences in CERAD-NAB subtest performances between these two groups. MMSE scores are presented as raw scores, whereas for the other CERAD-NAB subtests age-, gender- and education-adjusted *z*-scores according to the norms provided by a large healthy elderly Swiss German sample are displayed, thus allowing for comparison between the test performances of the two patient groups and the test performances of demographically-matched healthy old adults.

The MMSE scores for both patient groups were in the range regarded as typical for MCI and mild AD patients, i.e., for the MCI group between 24 and 30 and for the mild AD group between 18 and 30. Compared to the healthy normative sample, as a group the MCI patients showed mild cognitive impairments (test performances between one and two standard deviations below demographic-adjusted norms) in the three CERAD-NAB word lists subtests only, whereas the mild AD patients showed severe cognitive impairments in these three subtests (test performances two or three standard deviations below demographic-adjusted norms) and additionally mild cognitive impairments in the semantic fluency, Boston Naming and constructional praxia delayed free recall subtests. Only for the constructional praxia subtest, the AD patients showed a similar performance as the healthy normative sample (their median test performance approximated the norm). Therefore, the MCI patients had predominantly a mild verbal retrospective memory deficit, whereas the AD patients had a severe verbal and a mild visual retrospective memory deficit along with mild language impairments.

To assess differences in CERAD-NAB subtest performances between the MCI and AD patients, independent *t* tests were carried out on all CERAD-NAB subtests but constructional praxia. Since constructional praxia scores were not normally distributed, the Mann-Whitney test was used instead. Results of these analyses are displayed in Table 16 and indicate that the MCI patients performed significantly better than the mild AD patients on all CERAD-NAB subtests except constructional praxia for which no group differences were found. The difference between MMSE scores, however, was only marginally significant.

Table 16. ***Comparison of the MCI and AD Patients for the CERAD-NAB Subtests***

	MCI (n = 27) M (SD)	AD (n = 9) M (SD)	Independent t test t (df)
MMSE	27.44 (2.08)	25.78 (3.53)	1.73 (34)[†]
Semantic fluency	-0.54 (1.15)	-1.43 (0.59)	2.19 (34)*
Boston Naming test	-0.43 (1.22)	-1.60 (1.65)	2.28 (34)*
Constructional praxia[a]	0.66 (10.05)[b]	0 (4.25)	U = 106.00
Word list learning	-1.34 (1.69)	-2.48 (0.86)	2.65 (27.77)*
Word list delayed free recall	-1.08 (1.48)	-2.76 (0.60)	4.83 (32.41)***
Word list delayed recognition	-1.26 (2.60)	-3.84 (2.76)	2.54 (34)*
Constructional praxia delayed free recall	-0.79 (1.50)	-1.87 (.86)	2.62 (24.80)*

Note. MMSE: raw scores; CERAD-NAB: age-, gender- and education-adjusted z-scores. [a]Medians, ranges and U are reported because the Mann-Whitney test was used as constructional praxia z-scores were not normally distributed. [b]n = 26. [†]p = .086. *p < .05. ***p < .001.

Since the scores of the neuropsychological tests that were completed by all participant groups (i.e., Digit Span forward and backward, TMT-B/A, third plate of the Stroop-Victoria Test) were not normally distributed, median raw scores and score ranges are presented in Table 17. It also provides the results of the Kruskal-Wallis tests and post hoc Mann-Whitney tests that were used to evaluate differences between the three groups on their shared neuropsychological tests.

According to the Kruskal-Wallis tests, there was a significant effect of participant group on all these neuropsychological tests. The post-hoc comparisons with Whitney-Mann tests revealed that the healthy controls and the AD patients outperformed the MCI patients on the Digit Span forward test, although the difference between the AD and the MCI patients was just marginally significant. There was no significant difference between the Digit Span forward scores of the healthy old adults and the AD patients. This indicates that only the MCI patients were impaired in short-term memory.

On all executive functions test (i.e., Digit Span backward, TMT B/A, and Stroop-Vicoria Test), the healthy old adults performed significantly better than both patient groups, whereas both patient groups did not differ in their test performances. Therefore, both patient groups seemed to be similarly impaired in working memory, task switching, and inhibition. However, the impaired test performance of the MCI patients on the Digit Span backward test seems to be accounted for by their impaired test performance in the Digit Span forward test. Consequently, it is assumed that only the AD patients were impaired in working memory.

As can be seen in Table 17, for the TMT-B/A data of seven MCI and two AD patients were missing. For these patients the TMT-B had proven too difficult to master, thus indicating severe task switching impairments, that were not accounted for in the group comparisons for the mean TMT B/A performance. There was a group difference for the percentage of participants not being able to complete the TMT-B, $\chi^2(1, N = 107) = 19.50, p < .001$. Significantly more healthy old adults than MCI patients ($\chi^2(1, N = 98) = 19.82, p < .001$) and AD patients ($\chi^2(1, N = 78) = 16.18, p < .001$) were able to complete the TMT-B, whereas both patient groups did not differ in the percentage of participants not able to master the TMT-B, $\chi^2(1, N = 36) = 0.49, p < .90$. These analyses confirm that compared to healthy old adults, both patient groups were similarly impaired in task switching.

In summary, these analyses reveal that compared to the healthy old controls, the MCI patients had a short-term memory deficit, a task switching, and an inhibition deficit, whereas the AD patients were impaired in working memory, task switching, and inhibition. MCI and AD patients were similarly impaired in task switching and inhibition.

Table 17. ***Comparison of the Participant Groups for Shared Neuropsychological Tests***

Test	Group	*n*	*Mdn* (Range)	Kruskal-Wallis X2 (2)	Post-hoc comparisons Group: *U*
Digit Span forward	C	70	7 (7)	13.72**	C vs. MCI: 462.5***
	MCI	25	6 (5)		C vs. AD: 237.0
	AD	9	6 (2)		MCI vs. AD: 97.5†
Digit Span backward	C	70	6 (8)	8.80*	C vs. MCI: 646.5*
	MCI	25	5 (8)		C vs. AD: 131.5*
	AD	8	4.5 (5)		MCI vs. AD: 72.0
TMT-B / A	C	71	2.23 (8.82)	16.59***	C vs. MCI: 347.0**
	MCI	20	2.86 (8.40)		C vs. AD: 101.0*
	AD	7	3.00 (4.36)		MCI vs. AD: 64.0
3rd plate Stroop	C	70	26 (49)	21.96***	C vs. MCI: 427.0***
	MCI	25	37 (76)		C vs. AD: 100.0**
	AD	9	41 (96)		MCI vs. AD: 82.0

Note. C = Control group. Raw tests scores are presented. For Digit Span forward and backward possible minimum and maximum scores are 0 and 12. For the 3rd plate of the Stroop-Victoria test times in s are reported. Medians and ranges are reported and the Kruskal-Wallis test and the Mann-Whitney test were used to evaluate differences between groups because test scores were not normally distributed. $^{\dagger}p$ = .086. *p < .05. **p < .01. ***p < .001.

5.3.3. Group difference in prospective and retrospective memory complaints

In Table 18, the mean PRMQ Prospective and the mean Retrospective Scale scores for each of the three participant groups and the whole sample are presented. Additionally, in the last column of Table 18 the means for the average between the Prospective and Retrospective Scale scores for each participant group and the whole sample are provided.

Table 18. ***Comparison of the Participants Groups for the PRMQ Prospective (PS) and Retrospective Scale (RS) Scores***

Group	*n*	PS *M* (*SD*)	RS *M* (*SD*)	Average between PS and RS *M* (*SD*)
Control	70	19.06 (0.59)	18.87 (0.54)	18.96 (0.53)
MCI	27	18.85 (0.95)	18.56 (0.87)	18.70 (0.85)
AD	9	17.22 (1.64)	20.56 (1.51)	18.89 (1.47)
whole sample	106	18.38 (0.66)	19.38 (0.61)	18.85 (0.59)

A 3x2-mixed ANOVA with participant group as between-subject factor and type of memory complaint (i.e., Prospective versus Retrospective Scale of the PRMQ) as within-subjects factor was conducted to assess whether the participant groups differed in the amount of prospective versus retrospective memory complaints. The main effect of group was not significant ($F(2, 103) = 0.03$; $p < .97$), indicating that the groups did not differ in the amount of reported memory failures (regardless of which type). As can be seen in the last column of Table 18, the means of the average between the Prospective and Retrospective Scale scores were very similar for all groups. There was a main effect of type of memory complaint, $F(1, 103) = 4.16$; $p = .044$. As can be seen in the last row of Table 18, the mean Prospective Scale scores of the whole sample were lower than the mean Retrospective Scale scores of the whole sample. This indicates that in the whole sample more retrospective than prospective memory failures were reported. Furthermore, there was an interaction between participant group and type of memory complaint, $F(2, 103) = 4.33$; $p = .016$. As can be deducted from Table 18, the Prospective and Retrospective Scale scores of the healthy old adults and the MCI patients were very similar, whereas the Retrospective Scale scores of the AD patients were greater than their Prospective Scale scores. Post-hoc paired *t* tests confirmed that there was no difference between the Prospective and Retrospective Scale scores of the healthy old adults ($t(69) = -.55$, $p < .60$) and of the MCI patients ($t(26) = -.35$, $p < .80$), whereas the difference between the Retrospective and Prospective Scale scores was marginally significant for the AD patients, $t(8) = 2.22$, $p = .057$. Therefore, the main effect of greater Retrospective than Prospective Scale scores was probably mainly caused by the greater Retrospective than Prospective Scale scores of the AD patients. In conclusion, these analyses indicate that the participant groups did not differ in their mean level of prospective and retrospective memory complaints. However, the AD patients reported more retrospective than prospective memory complaints, whereas the healthy old participants and the MCI patients complained as much about prospective as about retrospective memory failures.

5.3.4. Relation of prospective and retrospective memory complaints to executive functioning in healthy old adults and MCI patients

To assess whether prospective memory complaints were differentially associated with executive functioning for both healthy old adults and MCI patients, in a first step correlations between the PRMQ Prospective and Retrospective Scale scores, demographic variables, and depressive affect were calculated. When the correlations between the two PRMQ Scale scores and these variables were significant, they were controlled for in the calculation of the correlations between the Prospective and Retrospective Scale scores and executive function tests scores (i.e., a working memory test, a task switching, and an inhibition test). Additionally, the correlations between the two PRMQ Scale scores and the short-term memory test scores were calculated to assess whether it would be necessary to control for the influence of short-term memory when calculating the correlations between the two PRMQ Scale scores and the working memory test. All correlations were calculated separately for the healthy old adults and the MCI patients. The results of these analyses are displayed in Table 19.

5.3.4.1. Correlations of prospective and retrospective memory complaints with demographic variables, depressive affect, and short-term memory

Next to depressive affect (for healthy old adults HADS depression subscales scores, for MCI patients GDS scores) and the short-term memory measure (Digit Span forward scores), age, gender, years of schooling, and crystallized intelligence were included in the analyses. For the healthy old adults, the Prospective Scale scores were related to depressive affect only, whereas the Retrospective Scale scores were related to depressive affect and age. All these correlations were positive and of moderate size. For the MCI patients, the Prospective Scale scores did not correlate with any of the variables, whereas the Retrospective

Scale scores were correlated with crystallized intelligence. This correlation was negative and of moderate size.

Table 19. ***Correlations between the PRMQ Prospective (PS) and Retrospective Scale Scores (RS) and Demographic Variables, Depressive Affect, Short-Term Memory, and Executive Functions for Healthy Old Adults and MCI Patients***

	Controls		MCI	
	PS	RS	PS	RS
Age	r = .10 (71)	r = .26 (71)**	r = -.14 (27)	r = -.03 (27)
Gender	φ = .49 (71)	φ = .55 (70)	φ = .78 (27)	φ = .91 (27)
Education	r = .04 (71)	r < .01 (70)	r = .05 (27)	r = .10 (27)
Crystallized Intelligence	r = .06 (71)	r = .07 (70)	r = -.21 (25)	r = -.41 (25)*
Depression	r = .30 (71)*	r = .36 (70)**	r = .34 (27)	r = .27 (27)
Digit Span Forward	pr^a = -.08 (65)	pr^b = .03 (65)	r_s = .35 (25)	pr^c = .33 (20)
Digit Span Backward	pr^a = -.05 (67)	pr^b = -.13 (65)	r_s = -.06 (25)	pr^c = -.06 (20)
TMT-B /A	pr^a = .24 (68)*	pr^b = .34 (66)**	r_s = .10 (20)	pr^c = .56 (16)*
3rd plate Stroop	pr^a = .23 (67) †	pr^b = .06 (65)	r_s = .40 (25)*	pr^c = .01 (21)

Note. Correlations are presented with *N* in brackets. Depression: in controls HADS depression subscale scores, in MCI patients GDS scores. [a]controlling for age and depression; [b]controlling for depression; [c]controlling for crystallized intelligence. †p = .052 *p < .05. **p < .01.

5.3.4.2. Correlations of prospective and retrospective memory complaints with executive functions tests

The Digit Span backward scores as a measure for working memory, the TMT-B/A scores as a measure for task switching, and the Victoria-Stroop Test scores as a measure for inhibition were included in the analyses as executive functioning measures. If applicable, partial correlations controlling for those demographic or affective variables that were found to be correlated with the Prospective Scale scores (for healthy old adults depressive affect) and the Retrospective Scale scores (for healthy old adults depressive affect and age; for MCI patients crystallized intelligence) in the previous analysis were calculated. For healthy old adults, the Prospective Scale scores were found to be related to the TMT B/A scores. In addition, the correlation between the Prospective Scale scores and the Victoria-Stroop Test scores was marginally significant. For the MCI patients, the Prospective Scale scores were related to the Victoria-Stroop Test scores only. For both healthy old adults and MCI patients, the Retrospective Scale scores were related to the TMT B/A scores. Both correlations were positive and of moderate size.

5.4. Discussion

The aims of this study were to evaluate (a) the usefulness of subjective prospective in comparison to subjective retrospective memory complaints for a screening for MCI and (b) the appropriateness of the proposal that insight in everyday prospective, but not retrospective memory competence, is related to executive functioning in healthy old adults and patients with MCI.

For the first aim, 71 healthy old adults, 27 individuals with a clinical diagnosis of MCI, and 9 individuals with a clinical diagnosis of mild AD were asked to complete the Prospective and Retrospective Memory Questionnaire (PRMQ). Their scores on the Prospective Scale of the PRMQ were used as a measure for subjective prospective memory complaints and their scores on the Retrospective Scale of the PRMQ as a measure of subjective retrospective memory complaints. Since previous findings indicate that prospective memory is an equally sensitive marker as retrospective memory for preclinical and mild AD and awareness of everyday prospective memory deficits is greater than awareness for everyday retrospective memory deficits, it was anticipated that all participant groups complain more about prospective than retrospective memory failures. Additionally, it was expected that the MCI patients would report more prospective and retrospective memory failures than the healthy old adults and that the AD patients report more prospective memory failures than the MCI patients, but a similar amount of retrospective memory failures. Contrary to these predictions, we found that both the healthy old adults and the MCI patients complained as much about prospective and retrospective memory deficits, while the AD patients even complained more about retrospective than prospective memory problems. Additionally, neither the amount of subjective prospective nor retrospective memory complaints could discriminate the MCI patients from the healthy old adults nor the AD patients. However, the difference between subjective prospective and retrospective memory complaints distinguished the patients with mild AD from the other two participant groups, thus suggesting the usefulness of assessing both subjective prospective and retrospective memory complaints for a screening for mild AD.

To evaluate whether insight in everyday prospective memory competence is specifically related to executive functioning in healthy old adults as well as in MCI patients, correlations between their scores on the Prospective and Retrospective Scale of the PRMQ and three executive function tests were calculated separately for the two participant groups, controlling, if applicable, for associations between the two PRMQ scales with demographic variables, depressive affect and short-term memory. It was expected that for both healthy old adults and MCI patients, their scores on the Prospective Scale, but not on the Retrospective Scale of the PRMQ, were related to their scores on executive functions tests. Although the scores of our healthy old adults and MCI patients on the Prospective Scale were correlated with their scores on one of the three executive functions tests, in contrast to the predictions their Retrospective Scale scores were also correlated with one of the executive functions tests. Nevertheless, a differential pattern of associations emerged: the Prospective Scale scores of both participant groups were correlated to their scores on the inhibition test, while their Retrospective Scale scores were correlated to their scores on the task switching test. Moreover, we found a differential pattern of associations between the amount of subjective prospective and retrospective memory complaints and depressive affect and demographic variables in the healthy old adults and MCI patients. For the healthy old adults both their Prospective and Retrospective Scale scores were correlated to depressive affect and additionally their Retrospective Scale scores to age. In contrast, the Prospective Scale scores of the MCI patients were not related to any of the control variables, whereas their Retrospective Scale scores correlated with crystallized intelligence.

With regard to previous empirical evidence, particularly by Kliegel and Jäger (2006) who reported significantly more subjective prospective than retrospective memory complaints using the same version of the PRMQ in a similar sample of Swiss healthy old adults, it was surprising that the healthy old adults of our study reported a similar amount of subjective prospective and retrospective memory complaints. This differential finding might be caused by the exclusion of healthy old participants with depression questionnaire scores suggestive of the presence of a depressive episode in our study, whereas in the previous studies depressive symptomatology was not specifically screened for. Zeintl, Kliegel, Rast, and Zimprich (2006) reported that only for high prospective memory complainers in their Swiss population-based healthy elderly sample, the amount of subjective prospective memory complaints as measured with the PRMQ Prospective Scale was related to depressive affect. This suggests that we probably excluded particularly high prospective memory complainers, and, therefore, found a similar average amount of subjective prospective and retrospective memory complaints in our remaining healthy old participants.

Only for the healthy old adults in our study, the amount of prospective and retrospective memory complaints was positively related to their level of depressive affect. For the MCI and the AD patients, we did not find a correlation between their depression questionnaire scores and their prospective or their retrospective complaint level. This might explain why neither the amount of subjective prospective nor retrospective memory complaints distinguished the healthy old adults from the MCI patients or the mild AD patients.

One possible reason why both subjective prospective and retrospective memory complaints did not discriminate the MCI patients from the healthy old adults in our study may be that they were relatively mildly impaired in retrospective memory compared to the MCI patient groups in the previous studies (Clément, Belleville, & Gauthier, 2008; De Jager & Budge, 2005; Perrotin, Belleville, & Isingrini, 2007) that demonstrated that MCI patients report a higher level of subjective memory complaints than healthy old adults. In these studies, test performance of at least 1.5 standard deviations below age-adjusted norms was used to define memory impairment, whereas we used a cut-off score of one standard deviation only. It might be possible that because of their mild impairment, our MCI patients were still able to manage everday retrospective and prospective memory tasks. Moreover, MCI patients may not complain more about prospective than retrospective memory deficits because the more negative practical and social consequences of prospective memory failures caused them to put more effort in managing prospective memory tasks. Specifically, they could have used more external memory aids, such as calendars or notebooks, for managing their daily prospective memory tasks, since reliance on such prospective memory aids is a common and very accepted practice in the general population (Long, Cameron, Harju, Lutz, & Means, 1999). Findings by Marsh, Hicks, and Landau (1998) indicate that mild retrospective memory deficits can be in fact compensated by the use of daily planners. They reported young healthy adults that habitually used daily planners for managing their everday prospective memory tasks had worse retrospective memory abilities than young healthy adults who did not use daily planners, but were able to complete a similar amount of prospective memory tasks during one week. Furthermore, it has been often demonstrated that although healthy old adults perform worse than healthy young adults on laboratory prospective memory tasks, they are at least as good as young adults in naturalistic prospective memory tasks which has often been explained by their greater reliance on external memory aids in daily life (for a review see Philipps, Henry, & Martin, 2008).

In contrast to the MCI patients, the mild AD patients in this study were severely impaired in retrospective memory tasks. Therefore, the finding that they reported a similar level of prospective and retrospective memory failures as the healthy old adults and the MCI patients seems to be caused by a diminished insight in the severity of their prospective and retrospective memory impairment. However, since they reported more retrospective than prospective memory impairments, their insight in their retrospective memory competence seem to be more preserved than their insight in their prospective memory impairments. On the other hand, Smith et al. (2000) reported that carers of AD patients are more frustrated about the patients' prospective than retrospective memory failures. Therefore, they may relieve the AD patients from many everyday prospective memory tasks. Consequently, the AD patients may indeed experience fewer everyday prospective than retrospective memory failures. Alternatively, it might be easier for the AD patients and their carers to identify and accept retrospective memory failures since their physicians presented them as the core symptom of the disease, whereas they did not mention prospective memory failures because of their little familiarity with this type of episodic memory.

In any case, there is support for the assumption that MCI and mild AD patients regard semantic instead of episodic memory impairments as most interfering with their normal life. Kalbe and colleagues (2005) found that among all cognitive abilities questioned in their interview, their MCI patients reported only significantly more and their AD patients a very similar amount of word finding difficulties than their carers. These word finding difficulties might lead to failures in everyday situations regarded as representative for retrospective episodic memory, as they impair the retrieval of the specific names of acquaintances, places, books, films, or TV programmes. This would also explain why in this study the amount of retrospective memory complaints of the MCI patients were positively related to their crystallized intelligence scores. Crystallized intelligence was measured with a vocabulary test which could also be considered as a measure for word finding. The healthy old adults had higher scores on this test than the MCI patients although their level of schooling was similar, suggesting very mild semantic memory impairments in the MCI patients. Moreover, this proposal is in line with the findings of Clément and colleagues (2008) showing that both their MCI and mild AD patients had only significantly higher scores than their healthy old adults on the subsection of their memory questionnaire relating to memory for films and books, conversations, and places. Therefore, subjective semantic memory complaints may be more useful in discriminating healthy old adults from MCI and mild AD patients.

In our study, we could not confirm Mäntylä's (2003) proposal of a differential relation of subjective prospective memory complaints to executive functioning, since both the Prospective and Retrospective Scales of the PRMQ complaints were correlated with executive functions tests. This might be caused by the fact that the Retrospective Scale included a similar amount of questions relating to tasks demanding self-initiated retrieval as the Prospective Scale. In line with this suggestion, Dubreuil, Adam, Bier, and Gagnon (2007) could not find a significant correlation between subjective memory complaints with a classical retrospective memory task. However, when they separated controlled and automatic memory processes in this task with the Process Dissociation Procedure, they could demonstrate a significant correlation between subjective memory complaints and the controlled processes. However, we found differential pattern of associations of the Prospective and Retrospective Scale with different types of executive functions, indicating that everyday prospective and retrospective memory tasks may rely on different executive skills. Additionally, the differential associations of both PRMQ scales with demographic variables and depressive affect in the healthy old adults and the MCI patients suggest that both groups base the evaluation of their everyday prospective and retrospective memory competence on different information.

In conclusion, our results indicate that the assessment of subjective prospective and retrospective memory complaints with the Prospective and Retrospective Scales of the PRMQ is useful for the discrimination of mild AD patients from healthy old adults and MCI patients. However, the mild AD patients could not be reliably distinguished from the other groups by a greater amount of prospective or retrospective memory complaints but by a greater amount of retrospective relative to prospective memory complaints. The discriminative power of a questionnaire measuring subjective memory complaints between healthy old adults, MCI patients, and mild AD patients could be improved by additionally recording their reliance on external memory aids and their everyday memory demands. Additionally, it would be worthwhile to evaluate whether a questionnaire relating specifically to semantic memory complaints might be a useful screening instrument for MCI. Furthermore, more direct research on the information healthy old adults, MCI patients, and AD patients use to evaluate their everyday cognitive competence and on possible perception and interpretation distortions is needed.

6. General Discussion

This chapter is divided into two main parts. In the first part, the main results of each of the four empirical studies are presented separately and discussed. Limitations of the studies are outlined and suggestions are made on how to resolve these in future studies. In the second part, the findings of the four studies are integrated and broader practical, methodological, and conceptual implications are discussed. Within the first part, the first and fourth study of the thesis will be covered each in one section. The second study and the third study are presented together in one section, because they are closely related to each other.

6.1. Study 1: The Role of Executive Functions for the Four Phases of Prospective Memory - Comparison of Young and Old Healthy Adults and Traumatic Brain Injury Patients with a Selective Executive Functions Deficit

The aim of the first study was to disentangle the respective roles of executive functions and retrospective episodic memory deficits of healthy old adults for their performance decrements (as compared to healthy young adults) previously observed in the intention formation, initiation, and execution phases of the paradigm by Kliegel, McDaniel, and Einstein (2000).

For this purpose, 7 traumatic brain injury (TBI) patients with normal retrospective episodic memory according to delayed recall indices of the Wechsler Memory Scale-Revised (Härting et al., 2000) and impaired executive functions as indicated by sum scores on the Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996), 20 healthy old adults, and 19 healthy young adults completed the prospective memory paradigm by Kliegel, McDaniel, and Einstein (2000). To compare all three groups directly for their executive functioning, all three participant groups additionally completed the Wisconsin Card Sorting Test (WCST, Heaton, Chelune, Talley, Kay, & Curtiss, 1993)

The main findings of the study are the following. Intention retention was very high and did not differ between the three experimental groups. The young healthy adults performed better than the old healthy adults and the TBI patients in intention formation, initiation, and execution. The old healthy adults and the TBI patients did not differ in their performance in these phases of the paradigm. It was also demonstrated that the healthy young adults performed better than both the healthy old participants and the TBI patients in the additionally included executive functions test, whereas the two latter groups performed similarly in this test.

The performance of the TBI patients as compared to the healthy young adults in this paradigm is in line with the proposal that intention formation, initiation, and execution of a delayed intention involving a complex activity depend on executive functioning, whereas intention retention relies on retrospective episodic memory skills. The equal performance of the old healthy participants and the traumatic brain injury patients in the additionally included executive functions tests as well as in the prospective memory paradigm by Kliegel, Einstein, and McDaniel (2000) suggests that the performance decrements of old healthy adults as compared to young healthy adults in intention formation, initiation, and execution reported in earlier studies (see Kliegel, Mackinley, & Jäger, 2008b for an overview) are mainly caused by their executive functioning deficits. Moreover, this result suggests that retrospective episodic memory deficits often seen in healthy older adults do not seem to influence their performance in the different phases of the prospective memory process and, consequently, that unique memory processes are involved in the encoding, retention, and retrieval of delayed intentions. However, this conclusion does not have a very firm basis, since retrospective episodic memory was not measured in the healthy old and in the healthy young participants. Therefore, it is unclear whether these two groups and the TBI patients have similar retrospective episodic memory skills.

Another methodological limitation of the study is clearly the small group size of the TBI patients. Thus, the power of the statistical analyses was low, particularly challenging the non-significant findings. Furthermore, other cognitive abilities which may have also been impaired in healthy old adults and the traumatic brain injury patients were not taken into account and may have also affected task performance. Another critical issue is that the phases of the Kliegel, Einstein, and McDaniel (2000) paradigm are not independent from one another. Consequently, one could claim that when the TBI patients and old healthy adults already performed worse than the young healthy adults in the intention formation phase, then their performance in the following phases must also be impaired. Then the finding that the TBI patients and the old healthy adults performed worse than the young healthy adults in the intention initiation and execution phases would no longer exclusively support the conclusion that in each of these phases executive functions are needed.

In future studies, the first methodological limitation of the study could be easily overcome by measuring both retrospective episodic memory and executive functions in all experimental groups. Even more methodologically stringent would be to match TBI patients, old healthy adults, and young healthy adults individually according to their scores on a retrospective episodic memory test and on an executive functions test. However, this would require that a markedly greater number of young and old healthy adults need to be tested in order to identify individuals that show the desired scores in comparison to those of the TBI patients on the retrospective episodic memory as well as the executive functions test. The other limitations are more difficult to resolve. We only found 10 TBI patients with normal episodic retrospective memory and impaired executive functions in a data base of over 500 patients of a major neurological clinic, indicating that such a condition is very rare. Therefore, to take into account other cognitive variables, i.e., to find patients with even more selective executive functions deficits, will be very difficult. Concerning the dependency of the latter phases in the paradigm by Kliegel, McDaniel and Einstein (2000) on the previous ones, one could try to match the performance of the three experimental groups in the first phase by providing the groups with a plan for the complex activity, but it will be very hard to match their performance in the other phases. Anyhow depend the phases of the prospective memory process on each other, therefore it will be very difficult to measure or influence them independently.

Despite its limitations, this study was the first to include: (a) TBI patients with impaired executive functions *and* normal retrospective episodic memory, (b) *and* a group of healthy old adults in addition to a group of healthy young adults, and (c) having them all complete the *paradigm by Kliegel, McDaniel, and Einstein (2000)*. Earlier studies on prospective memory that included patients selected them only by their disease or the location of their brain damage and used only the Einstein-McDaniel-paradigm. Moreover, the performance of the patients was not explicitly compared to that of healthy old adults (for overviews see Kliegel, Jäger, Altgassen, & Shum, 2008; West, 2008).

In a more general sense, the findings of the study suggest that old healthy adults and neurological patients with executive functions deficits may have problems in planning, initiating, and executing complex intended activities in daily life. Therefore, future research should concentrate on methods to overcome these problems. A first attempt in this direction has been made by Kliegel, Martin, McDaniel, Einstein, and Moor (2007). They could demonstrate that healthy old adults' performance decrements (as compared to healthy young adults) in the intention formation, initiation, and execution phases of the Kliegel, McDaniel, and Einstein (2000) paradigm can be alleviated by helping them to plan the complex intended activity. Moreover, Kim, Burke, Dowds, Robinson Boone, and Parks (2000) and Thöne-Otto and Walther (2003) have demonstrated, that neurological patients can be supported in realizing complex everyday intended activities with electronic devices such as palmtop computers or mobile phones. These allow the carers of the patients to enter single action steps of an intended complex activity and their execution times, remind the patients of these steps at the right time, and to guide them through their execution.

6.2. Studies 2 and 3: Motor Preparatory Processes in Prospective Memory Encoding in Young and Old Healthy Adults

The general aim of the second and third studies of the thesis was to provide more direct evidence for the suggestion that age-invariance in free recall for delayed intentions involving verbal action descriptions is based on the recruitment of motor preparatory processes during encoding that are unaffected by aging. Both studies used fMRI because this technique can provide direct measures for cognitive processes involved in encoding.

6.2.1. Study 2: Motor preparatory processes in young adults

The specific goal of the second study of the thesis was to test the proposal that motor preparatory processes are recruited during encoding of delayed intentions involving verbal action descriptions.

For this purpose, 10 healthy young participants were scanned during the encoding of 24 action verbs for later enactment with the right arm, 24 action verbs for later verbal report, and 24 abstract verbs for later verbal report. Subsequent recall mode (enactment versus verbal report) was signalled by the colour of the verbs. Afterwards, the participants were asked to enact or to report the verbs encoded for the respective recall mode. Additionally, they were questioned about strategies they had adopted during the encoding of verbs for later enactment versus later verbal report. The study participants were screened for neurological, systemic, or psychiatric disorders or substance abuse known to affect brain function as well as for cognitive deficits.

The first main finding of this study was that during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report following brain regions in the left hemisphere were more highly activated: the dorsal premotor cortex, the ventral premotor cortex, the inferior parietal lobule, the postcentral gyrus, the precuneus, and the posterior middle temporal gyrus. These brain regions have been found to be activated in covert motor tasks concerning hand movements, such as imagery, observation, verbalization, and retrieval of knowledge about hand movements. Moreover, many of these brain regions have been found to be activated during preparation delays for later hand movement execution. Consequently, this finding is in line with the proposal that during the encoding of delayed intentions involving verbal action descriptions, motor preparatory processes are engaged for the to-be-enacted actions.

The second main finding of this study was that during the encoding of action verbs as compared to abstract verbs for later verbal report the right dorsal premotor cortex was more highly activated. Thus, there was no overlap between the more highly activated brain regions during the encoding of action verbs for later enactment versus later verbal report and the more highly activated brain regions during the encoding of action verbs versus abstract verbs for later verbal report. Consequently, those brain regions that were found to be more highly activated during the encoding of action verbs for later enactment as opposed to encoding of action verbs for later verbal report seem to be specifically involved in the preparation of a later motor response and are not only more highly activated because of higher demands on retrieval of action-related knowledge about the to-be-enacted in contrast to the to-be-reported action verbs.

A clear limitation of this study was that there was no significant recall advantage for the to-be-enacted in comparison to the to-be-reported action verbs. This may be caused by the small sample size. As typically in fMRI studies because of their high costs, only 10 participants took part in the study. Furthermore, this effect may have been masked by the altogether high memory load of 72 verbs. However, the fMRI technique demands participants to engage in longer periods of experimental tasks to acquire meaningful data. Another limitation of this study was that the participants reported that they had imagined themselves or another person enacting the to-be-enacted action verbs during encoding, whereas they stated to have used more semantic or no specific encoding strategies during the encoding of action verbs or abstract verbs for later verbal report. Many of the brain regions that were more highly activated during encoding of action verbs for later enactment in contrast to encoding of action verbs for later verbal report have been previously found to be involved in imagery of actions. Therefore, it is unclear whether the brain regions that were more highly activated during the encoding of action verbs for later enactment versus later verbal report were related to the differential imagery of the to-be-enacted actions or to motor preparatory processes for their later execution.

6.2.2. Study 3: Motor preparatory processes in young adults

The main goal of the third study of the thesis was to provide more direct evidence for the hypothesis that the motor preparatory processes recruited during the encoding of delayed intentions involving verbal action descriptions are unaffected by aging and are the basis for the age-invariance in free recall for delayed intentions so far observed in prospective memory research. A second aim of the study was to suppress differential imagery of to-be-enacted action verbs in order to determine to what extent the brain regions more highly activated during the encoding of action verbs for later enactment as opposed to encoding of action verbs for later verbal report in the second study of the thesis were related to imagery of the to-be-enacted actions.

After extensive screening procedures for neurological, systemic, or psychiatric disorders, or substance abuse known to affect brain function and for cognitive deficits, 16 young healthy and 14 old healthy adults participated in this study. In the neuropsychological screening examination, the old participants showed overall typical age-related deficits and preservations in the tested cognitive abilities (Park, 2000; Schaie, 2005). Thus, our samples seemed to be quite representative for their respective general population. Particularly relevant for the research question, the old adults performed worse than the young adults in a delayed free recall test for two short stories. To suppress differential imagery of to-be-enacted actions, the paradigm of the second study of the thesis was modified in the following way. The participants were not only presented action verbs, but simultaneously also short videos of a human model pantomiming the respective actions with the right arm. Consequently, the former condition of encoding of abstract verbs for later verbal report was replaced by a condition in which the participants were asked to watch similar action stimuli as in the other two conditions. This had also the advantage that compared to the previous fMRI study the overall memory load could be reduced. Moreover, in addition to the subsequent recall test for the to-be-enacted and to-be-reported action verbs, a recognition test was implemented. Another methodological improvement was that the participants were also asked to rate all action verbs for familiarity, imaginabilty, concreteness, and executabilty with one arm. No statistical differences between the action verbs used in the three experimental conditions in these variables as well as in number of letters and syllables were found, showing that they were well matched.

In contrast to the first study, a memory advantage for action verbs encoded for later enactment as compared to action verbs encoded for later verbal report could be demonstrated by significant faster recognition latencies, a higher recognition accuracy as well as a higher recall accuracy for the to-be-enacted verbs. As in earlier studies with semantically un-related action verbs or phrases (Freeman & Ellis, 2003b; Norris & West, 1993) for all retrieval measures, the memory advantage for the actions encoded for later enactment was of similar size for the young and the old participants, but the young participants outperformed the old participants on all retrieval measures with the exception of recognition accuracy (but the statistical test for this difference just failed to reach significance).

The first main finding of this study was that there was a great overlap between the brain regions more highly activated during the encoding of action verbs for later enactment versus later verbal report in this and in the second study of the thesis, i.e., the left ventral premotor cortex, the left dorsal premotor cortex, the left inferior parietal lobule, the left precuneus, and the left postcentral gyrus. This implies that these brain regions are not simply related to imagery of the to-be-enacted action verbs, but are recruited in preparation for their later enactment. Based on a detailed analysis of previous neuroimaging studies, particularly on action imitation, following functions for these brain regions were proposed. The left ventral premotor cortex and inferior parietal lobule probably translate the semantic information inherent in the action verbs into motor representation of the to-be-enacted actions. Somatosensory copies of these rather abstract motor representations are produced in the precuneus and postcentral gyrus, whereas the dorsal premotor cortex prepares action execution according to these somatosensory copies. In line with the requirement in our studies that the actions had to be enacted with the right hand, only the left precuneus, postcentral gyrus, and dorsal premotor cortex were more highly activated. Additionally, these regions seem to store this information for later action enactment. This proposal for the roles of the left ventral premotor cortex and the left inferior parietal lobule is also strengthened by the fact that both regions (in addition to the right superior temporal gyrus) were more highly activated during the encoding of action verbs for later verbal report versus watching similar action stimuli. With reference to earlier neuroimaging findings, an explanation for differences in brain activation during encoding of action verbs for later enactment as opposed to encoding of actions for later verbal report between the previous and the present study was provided. The additional activation of the left pre-supplementary motor area, the right parahippocampus/hippocampus, and bilateral occipito-temporal regions in the present study is most likely related to an additional encoding of visuospatial properties of the to-be-enacted actions presented in the videos in order to guide their later execution. In contrast, in the previous study the sole presentation of action verbs placed greater demands on the retrieval of action-related knowledge about the to-be-enacted actions and, thus, led probably to the additional engagement of the left posterior middle temporal gyrus.

The second main finding of this study is that although the memory advantage for to-be-enacted actions was similar for both the young and old adults in all included retrieval measures, age-differences in brain activation during the encoding of actions for later enactment as compared to the encoding of actions for later verbal report were observed. In addition to the brain regions both participant groups engaged commonly for this task, the young adults activated the right caudate body and the old participants the right inferior parietal lobule and the right dorsomedial prefrontal cortex. The caudate nucleus has been observed to be particularly activated in visual categorisation tasks, in which appropriate motor responses to classes of stimuli have to be learned. It specifically receives input from visual occipito-temporal regions and projects to the pre-supplementary motor area (see Seger, 2008). In the light of a substantial age-related loss of caudate body volume (Raz et al., 2005) and connectivity (Taniwaki et al., 2007), the old adults may have relied more on motor representations of the action verbs stored in the parietal inferior lobules in order to prepare their later enactment. This strategy may have the consequence that the action videos are analysed for congruence with these internal action representations. The right inferior parietal lobule and the right dorsomedial prefrontal cortex have been shown to be specifically engaged in analyses of congruence between one own's action plans and visual action presentations (Decety and Chaminade, 2003; Schnell et al., 2007). A preliminary conclusion from this finding is that although the young and old adults handled the visual presentation of the to-be-enacted action verbs in the videos differently, they did not differ in the motor preparatory processes engaged for the later enactment of the action verbs. Thus, the motor preparatory processes recruited for the encoding of delayed intentions involving *verbal* action descriptions may be unaffected by aging.

However, as in earlier studies with semantically unrelated action verbs or phrases, the young participants outperformed the old participants in free recall for the to-be-enacted action verbs. Thus, a clear relation between probably preserved motor preparatory processes during encoding of verbal action descriptions in old healthy adults and age-invariance in free recall for them could not be demonstrated. On the other hand, the prospective memory paradigms devised by Einstein and McDaniel (1990) and Kliegel, McDaniel, and Einstein (2000) usually involve only one action (although in the latter case a complex one), whereas the Goschke and Kuhl (1993) paradigm employed here involves a far greater amount of to-be-enacted as well as to-be-reported actions. Moreover, with the to-be-enacted and to-be-reported actions being matched for many variables, the procedure leads to greater interference effects. Both greater memory load (Jennings, Nebes, & Yovetich, 1990) and greater interference (Gerard, Zacks, Hasher, & Radvansky, 1991) have been demonstrated to affect free recall in old adults more negatively than in young adults.

A limitation of this study is that it still remains unclear whether the additional presentation of the action videos indeed led to the total suppression of the differential imagery of the to-be-enacted actions in comparison to the to-be-reported actions. Although the presentation of pantomimes of both action types in the videos certainly reduced the amount of differential imagery of to-be-enacted actions in comparison to to-be-reported actions, for the to-be-enacted actions one may still be more inclined to visualize how one would enact the actions one-self later on. On the other hand, since the imagery of the to-be-enacted action verbs seems to occur spontaneously, it could be regarded as part of the preparatory processes for later action execution.

In a follow-up study, it would be useful to ask the participants directly to imagine the execution of solely presented to-be-enacted and to-be-reported action verbs during encoding and to see whether similar brain regions as in the second and third studies of the thesis are specifically activated when the encoding of the to-be-enacted action verbs is contrasted to the encoding of the to-be-reported action verbs. This procedure would also eliminate possibilities for a different handling of the simultaneous presentation of action verbs and videos by the young and old adults that may be the cause for the age-difference in brain activation during the encoding of action verbs for later enactment versus later report observed in this study. If this assumption is true, the differential brain activation between young and old adults should disappear. Another way to test the proposal of a greater reliance of the young adults on the visual information about the to-be-enacted actions and a greater reliance of the old adults on the motor representations of the action verbs in preparation for their later execution would be to film the enactment of the actions and analyze them for their congruity with the action videos. The young adults should produce more similar actions to those presented in the videos than the old adults. However, it may be difficult to determine a good measure for congruity and such an analysis is quite effortful.

A limitation of both fMRI studies is that the participants were asked to encode actions for later enactment with the right arm only. In both studies a network of left-lateralized brain regions was more highly activated during the encoding of action verbs for later enactment in comparison to the encoding of action verbs for later verbal report. The left ventral premotor cortex and inferior parietal lobule may be involved in the translation of the action verbs into motor presentations. However, it is unclear whether the left dorsal premotor cortex, the left precuneus, and the left postcentral gyrus were more highly activated because they are contralateral to the arm the actions had to be later executed with or are generally involved in motor preparation. To resolve this issue, it would be interesting to measure brain activity when participants encode action verbs for later enactment with the left instead of the right arm.

However, taken together, the findings of the second and third studies of the thesis provide more direct evidence than before for the hypothesis that motor preparatory processes are engaged during the encoding of delayed intentions involving verbal action descriptions and that these may be unaffected by aging. These motor preparatory processes may be exploited to improve retention for intended activities in daily life by retrieving action-related knowledge about the to-be-remembered activity during intention formation. For example, if one intends to call a friend in the evening, it would be useful to think about the actions involved with it: entering the door, picking up the phone, and dialling the number.

6.3. Study 4: Self-Reported Everyday Prospective versus Retrospective Memory Competence in Old Healthy Adults, Patients with Mild Cognitive Impairment, and Patients with Mild Alzheimer's Disease

The aim of the last study of this thesis was to extend previous findings on the sensitivity of prospective memory as a marker for early Alzheimer's disease (AD). Specifically, the usefulness of self-reports on everyday prospective in comparison to everyday retrospective memory competence in identifying individuals in the preclinical and mild clinical stage of AD was tested as well as their respective relations to executive functions tests in old healthy adults as well as in patients in the preclinical stage of AD.

Seventy-one healthy old adults, 27 patients with Mild Cognitive Impairment (MCI, i.e., a diagnostic entity for the identification of individuals in the preclinical stage of AD), and 9 patients with mild AD completed the Prospective and Retrospective Memory Questionnaire (PRMQ). The patients were recruited from a major memory clinic over a period of two years. Diagnosis was based on extensive clinical, neuropsychological, neurological, and radiological examinations. The healthy old adults were community dwelling old adults and were screened for neurological, systemic, or psychiatric disorders, or substance abuse known to affect brain function. They completed a short-term memory test and three executive functions tests that were included in the neuropsychological test battery of the patients. In addition, all participant groups completed a depression questionnaire. To assess whether self-reports on everyday prospective memory competence were differentially associated with executive function tests for both healthy old adults and MCI patients, in a first step correlations between the level of reported prospective and retrospective memory failures, demographic variables, depressive affect, and short-term memory were calculated. When the correlations with these variables were significant, they were controlled for in the calculation of the correlations between the frequency of self-reported everyday prospective and retrospective memory failures and the three executive function tests.

The three participant groups did not differ in age or gender. The healthy old adults had a higher educational attainment than the patients groups, which did not differ in this respect from each other. Compared to an age- and education-matched healthy normative sample the MCI patients had predominantly a mild verbal retrospective episodic memory deficit, whereas the AD patients had a severe verbal and a mild visual retrospective episodic memory deficit and mild language impairments. The AD patients were more impaired in the respective tests for verbal and visual retrospective episodic memory and language than the MCI patients. The old healthy adults outperformed both patient groups in all included executive functions tests, whereas the patient groups did not differ in their performance on these tests. On the short-term memory test, the old healthy adults and the AD patients performed equally well and better than the MCI patients.

The main findings are the following. First, despite the clearly demonstrated executive functions and retrospective episodic memory impairments of the MCI and AD patients, the three participants groups did not differ in their mean amount of self-reported everyday prospective or retrospective memory failures. However, there was a significant interaction between the type of reported memory failures and participant group. The old healthy adults and the MCI patients reported a similar amount of prospective and retrospective memory failures, but the mild AD patients reported more retrospective than prospective memory failures. Consequently, self-reports on everyday prospective memory failures alone do not seem to discriminate old healthy adults from patients in the preclinical or mild clinical stage of AD, but neither do self-reports on everyday retrospective memory failures. Only the respective amount of self-reported everyday prospective versus self-reported everyday retrospective memory failures may distinguish mild AD patients from the other two groups. Secondly, for healthy old adults and MCI patients, a significant correlation between the amount of self-reported prospective memory failures and performance on one of the three executive functions tests was observed. However, in both groups also the amount of self-reported retrospective memory failures was correlated to performance on one of the three executive functions tests. Therefore, a differential association between self-reported prospective memory failures and executive functions tests could not be demonstrated.

A clear limitation of this study is the small sample size of the mild AD patients, thus diminishing the power of the statistical analyses. Since there was no statistical difference between the participant groups for self-reported everyday prospective memory failures, one could assume that differences between these groups could not be detected because of the small sample size of the AD patients. However, when qualitatively looking at the data, contrary to what would be expected by the severity of their cognitive impairment, the AD patients reported less prospective memory failures than the MCI patients and these less than the old healthy adults. In contrast, the AD patients reported more retrospective memory failures than the healthy controls and these more than the MCI patients. Thus, from the qualitative pattern of the data, self-reported everyday retrospective memory failures may discriminate mild AD patients better from healthy old adults than self-reported everyday prospective memory failures.

Self-reports on everyday prospective memory failures are probably influenced by many other variables than cognitive abilities, e.g., on how many delayed intentions one generally has to manage over a period of time, on which aids one uses to accomplish prospective memory tasks, and on a person's general perception and interpretation tendencies for failures. These variables were not controlled for or, at least, recorded. Thus, the three participants groups may have differed in these variables. In addition, these variables may have differentially influenced their self-reports. Indeed, in this study a differential pattern of correlations between self-reported everyday prospective memory failures and demographic variables, depressive affect, short-term memory, and executive functions tests between the healthy old adults and the MCI patients was found. Furthermore, the amount of everyday self-reported prospective memory failures was related to different variables than the amount of self-reported everyday retrospective failures in both groups, suggesting the two types of self-reports are in addition influenced by different variables in both groups.

Moreover, the included sample of MCI and AD patients was selective because it represented only memory clinic attenders. Other people who may experience cognitive decline due to AD may not regard it as disease-related and, therefore, may not seek medical assessment. Therefore, among individuals in the preclinical or mild stage of AD, memory clinic attenders may report more everyday prospective and retrospective memory failures than those who do not seek medical advice. If this assumption is true, then the findings of this study question the sensitivity of self-reports on everyday prospective memory competence for detecting individuals in the preclinical or mild clinical stage of AD all the more. In addition, it is unclear whether MCI indeed represents a preclinical stage of AD. Although there is a markedly higher incidence of AD in individuals with MCI as compared to the general population (Petersen & Negash, 2008), a rather high percentage develops other dementias, remains stable, or even reverts to a cognitively intact status (Ganguli, 2006). Diagnosis of MCI or AD also critically depends on the concrete operationalization of diagnostic criteria, such as which instruments are used to determine the severity of cognitive deficits, impairment of everyday functioning, or the exclusion of other conditions affecting brain function. Thus, conclusions drawn from the findings of this study do not easily generalize to the whole population of patients with preclinical or mild AD. On the other hand, this problem is inherent to all studies on these patient groups.

In future studies, the problems of small sample size and selective sample of memory clinic attenders could be resolved by distributing the PRMQ to a large population-based sample of old adults, assessing them for MCI or mild AD, and then determining whether the amount of self-reported everyday prospective memory failures discriminates better than the amount of self-reported everyday retrospective memory failures between healthy old adults, MCI patients, and AD patients. Moreover, it would be useful to examine which variables influence self-reports on everyday prospective memory competence, and whether the influence of these variables differs between healthy old adults, MCI patients, and AD patients. For example, one may explore the relationship of self-reports on everyday prospective memory failures with busyness of life-style as determined with the Martin and Park Environmental Demands Questionnaire (Martin & Park, 2003) or with the use of memory aids as determined with the respective scale of the Prospective Memory Questionnaire (PMQ; Hannon, Adams, Harrington, & Fries-Dias, 1995). At the present, a lot of research is focused on improvement of the MCI diagnosis. Subclasses of MCI are determined and their predictive power for AD is evaluated (Petersen & Negash, 2008). In a future study, it would be therefore useful to include individuals with a subtype of MCI that has high predictive power for AD. With regard to MCI or AD diagnosis, a general need to standardize assessment procedures has been recognized (Mariani, Monastero, & Mecocci, 2007; Thompson & Hodges, 2002), but is probably difficult to implement in practise.

In conclusion, the findings of the fourth study of the thesis suggest that self-reports on everyday prospective memory competence are not useful in discriminating individuals in the preclinical and mild stages of AD from healthy old adults. However, the respective amount of self-reported everyday prospective versus self-reported everyday retrospective memory failures may be helpful for distinguishing mild AD patients from healthy old adults. Self-reports on everyday prospective memory failures were related to executive functions tests in both healthy old adults and MCI patients, but so were self-reports on retrospective memory failures. However, for self-reported everyday prospective and for self-reported everyday retrospective memory failures a differential pattern of correlations with other variables was found in both groups, suggesting they are influenced by different variables in both groups. Thus, more direct research on the information healthy old adults, MCI patients, and AD patients may use to evaluate their everyday cognitive competence is needed.

6.4. Summary and Outlook

Taken together, the four studies of the thesis helped to gain some new insights into cognitive processes influencing prospective memory performance in old age. The findings of the first study suggest that executive functions deficits often observed in healthy old adults may diminish their ability to successfully plan, punctually initiate, and effectively perform complex intended activities, even though they remember the intended activity as well as healthy young adults. The results of the second study indicate that motor preparatory processes are engaged during the encoding of action verbs for later enactment as opposed to the encoding of action verbs for later verbal report. The third study demonstrated that these motor preparatory processes are largely persevered in healthy old adults and lead to a similar memory advantage for the to-be-enacted action verbs in comparison to the to-be-reported action verbs as in young adults. The findings of the second and third studies suggest that delayed intentions involving actions are better retained and retrieved from memory than delayed intentions involving verbal intended activities in both young and old healthy adults. Since delayed intentions majorly employed in prospective memory research involve actions, the findings of the second and third studies offer one reason for the age-invariance in free recall for delayed intentions so far observed in prospective memory research which disagrees with the worse performance of healthy old adults demonstrated for free recall for other types of information. Finally, the last study showed that self-reports on everyday prospective memory competence did not discriminate between healthy old adults, patients in the preclinical and patients in the mild clinical stage of Alzheimer's disease, suggesting that they are only little influenced by the severity of executive functions or episodic memory deficits.

Practically, the findings of the first three studies implicate that healthy old adults' prospective memory performance may be improved by supporting them in planning, initiating, and executing complex intended activities or by transforming more abstract verbal intended activities into actions, e.g., by thinking about the actions needed for the activity "deciding for a place to go on holidays" such as sitting down at the computer, searching in the internet via mouse clicks, and writing down. Generally with the development of rehabilitation methods for prospective memory in mind, research on cognitive processes in intention formation seems to be most worthwile, since they can be targeted most easily. So far, research has focused on planning, i.e., studies using the paradigm of Kliegel, Einstein, and McDaniel (2000) including the first study of this thesis, or on encoding, i.e., studies using the paradigm by Goscke and Kuhl (1993) including the second and third studies of this thesis, of the *intended activities* only. In future, it would be very interesting to modify these paradigms thus that they also allow to examine planning or encoding of the *intended execution times*.

With regard to extending knowledge about cognitive processes influencing prospective memory performance in old age, the first three studies of this thesis could show that the use of cognitive neuroscience methods is very useful. Since prospective memory is a complex task involving several phases that are dependent from one another, is it very difficult to devise behavioural experimental tasks that can single out one cognitive process underlying prospective memory performance. By comparing the performance of healthy old adults to that of patients with a selective cognitive deficit as in the first study of the thesis, one can measure more directly how one cognitive process among those that are negatively affected in aging influence prospective memory performance. Furthermore, by the use of fMRI as in the second and third studies of the thesis, one can directly measure cognitive processes in terms of brain activation accompanying them and, thus, by comparing brain activation patterns of young and old healthy adults make conclusions about the unaffectness of these cognitive processes by aging. These methods could be also used in future studies focusing on other cognitive processes demanded in prospective memory, such as planning or retrieval. Particularly promising in this sense is also the use of EEG, since it provides measures for very fast cognitive processes. Indeed, with EEG the identification of the intended execution time and the retrieval of the intended intention can be measured separately and, thus, can be compared between young and old healthy adults (see West, 2008 for an overview).

Obviously, self-reports on everyday prospective memory competence are influenced by many other variables than actual performance. However, one could read the result of the last study of this thesis as evidence for the conclusion that the findings of the first three studies only apply to the laboratory tasks used in these studies, but little influence *everyday* prospective memory performance. This points to a more general problem of laboratory prospective memory research and, actually, all laboratory psychological research: Do translate findings from the laboratory into the real world ?

One road that could be taken to resolve this problem with regard to prospective memory research is to try to device laboratory paradigms that reflect everyday prospective memory tasks more than they do so far. On the one hand, the paradigms by Einstein and

McDaniel (1990) and by Kliegel, McDaniel, and Einstein (2000) are very simple in comparison to prospective memory demands in daily life: they require only the realization of one delayed intentions, whereas in real life people have to manage many delayed intentions simultaneously. They both also require the execution of actions, whereas in daily life we often form more abstract intended activities. The Goschke and Kuhl (1993) paradigm captures these characteristics of everyday prospective memory demands, but does not require the self-initiated punctual execution of the intended activities which we often have to manage. With regard to the latter point, particularly the Einstein and McDaniel (1990) paradigm imposes probably greater demands than usually observed for *punctually* executing delayed intentions in daily life. In this paradigm, several occasions for intention execution are integrated into an ongoing task and require the participants to switch between intention execution and working on the ongoing task. This is probably very seldomly required in daily life. More often, people finish one activity before they start a new one. Furthermore, the time window for puntual intention execution is the interstimulus interval of the ongoing task, thus only lasting a few seconds. In everyday life, the time windows for puntual execution are generally definitely larger. This points to another difference: in laboratory tasks the delay between intention formation and the intended time is maximal 30 minutes, whereas in daily life most delayed intentions have to be retained in memory much longer, some over the period of weeks. Furthermore, in laboratory tasks the delayed intentions are very abstract. In daily life, the intended activities and time points are related to many activities, persons, and objects that we encountered frequently and, thus, may remind us on our delayed intentions. Starting from these analyses, several different laboratory tasks could be designed that reflect everyday prospective memory tasks better than before, e.g., that require the execution of several intentions, allow one to finish one activity before starting with the execution of the intended activity, have a greater time window, a longer delay between intention formation and execution, and use more natural intentions. Then one could investigate how manipulations of these variables affect prospective memory performance, particularly differences in performance between young and old healthy adults or old healthy adults and old adults in different stages of Alzheimer's disease.

Another road that could be taken is to see how performance differences between people in daily life affect their performance in laboratory tasks. Probably, with a little reflection, one could name people who one thinks to be a good or bad manager of everyday prospective memory tasks. As shown in the last study, self-reports on everyday prospective memory failures seem not a very good measure for this competence. One criterion for regarding someone as a good manager of prospective memory tasks would be that they are able to manage many delayed intentions at once. Therefore, it would be interesting to see whether people who have to regularly manage many prospective many tasks at once perform better in laboratory prospective memory tasks than those that do have to manage only a little amount of prospective memory tasks in daily life. Despite of its problems, a first step in this direction could be the development of a questionnaire that measures everyday prospective memory demands, to distribute it to large amount of people, and, thus, acquire a measure for average everyday prospective memory task

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Curriculum Vitae

Education

2004 - 2008	University of Zurich, Department of Psychology Doctoral Candidate
2004 - 2008	Neuroscience Center Zurich International Ph.D. Program in Neuroscience
1994 - 2001	Humboldt-Universität zu Berlin Diploma in Psychology
1996 - 1997	University of Sheffield Studies in Psychology

Employment History

Since 2006	University of Zurich, Department of Psychology Research Assistant
2003 - 2006	Psychogeriatric University Hospital Zurich Neuropsychologist
2002 - 2003	University of Heidelberg, German Centre for Research on Ageing Research Assistant
2001 - 2003	University of Heidelberg, Department of Psychiatry Research Assistant, Neuropsychologist
1997 - 2001	Humboldt-Universität zu Berlin and University of Potsdam Research Associate

Research Grants

2006 - 2007	Forschungskredit Research Grant of the University of Zurich for the Project: „Age Differences in Brain Activation in Prospective Memory Performance“

Scholarships

1996 - 1997	Scholarship of the German Academic Exchange Service for Studies at the University of Sheffield